INSTRUCTIONS

FOR

OBSERVING THE TRANSIT OF VENUS,

DECEMBER 6, 1882,

PREPARED BY

THE COMMISSION AUTHORIZED BY CONGRESS,

AND

PRINTED FOR THE USE OF THE OBSERVING PARTIES BY AUTHORITY
OF THE HON. SECRETARY OF THE NAVY.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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[General Order.]

Navy Department, *Washington, August* 11, 1882.

The parties organized by the Secretary of the Navy to observe the Transit of Venus in December, 1882, under the authority of an act of Congress approved August 7, 1882, are organizations invested with naval character, and subject to naval rules, regulations, and discipline. The command of each party is assigned to the Chief Astronomer, to whose authority all others will be obedient.

The following is the order of rank and authority in each party, viz:

1. Chief Astronomer.
2. Assistant Astronomer.
3. Chief Photographer.
4. Assistant Photographer.

This order will be respected and followed as the order of rank and succession in each party under all circumstances, including the contingencies growing out of any separation of the party, or the happening of any vacancy.

The party destined for the coast of Patagonia, about to embark in the U. S. steamer Brooklyn, will be personally subject to the authority of the commanding officer while on board that ship, and to its discipline, police authorities, and regulations.

The gentlemen engaged in this interesting and important service will readily and fully understand that discipline, harmony, and co-operation are essential to its satisfactory performance as well as to their own safety and convenience, and that for this reason they have been required to assume the obligations, and are subjected to the rules of the naval service.

WM. E. CHANDLER,
Secretary of the Navy.

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NAVY DEPARTMENT, *Washington, August* 11, 1882.

The following instructions, prepared by the Commission on the Transit of Venus, are issued, under the authority of this Department, for the guidance and government of the parties charged with the duty of making the observations of the Transit. Every person engaged in the scientific operations is enjoined to study them carefully and to conform to them strictly.

WM. E. CHANDLER,
Secretary of the Navy.

INSTRUCTIONS

FOR

OBSERVING THE TRANSIT OF VENUS.

DECEMBER 6, 1882.

I.—INTRODUCTORY NOTE.

The following instructions were prepared primarily for the use of the parties organized by the U. S. Transit of Venus Commission. But as the transit will be visible in this country, they have also been adapted to the use of amateur observers who desire to be made acquainted with the methods by which they may make observations of value.

II.—SELECTION OF STATION.

In choosing ground for a station, it is most important to obtain good foundations for the instruments. Gravel is best, but a sandy soil is unobjectionable, if the sand is not dr y.

A nearly level spot, measuring at least sixty feet from north to south, is necessary for setting up the transit instrument and photoheliograph. The floor of the photographic house must be eight and a half inches lower than that of the transit house, and it will be advantageous if the natural slope of the ground gives that amount of fall; but if it does not, one or other of the houses must be elevated to obtain the proper difference of level between them. For the sake of dryness, the sills of the houses should be raised three or four inches above the surface of the soil. In many situations this can be conveniently done by driving stakes about four inches square into the ground, setting the houses upon them, and nailing them fast. In other places it may be necessary to use small piers of stone or brick.

Shelter from the prevailing winds is to be sought for; but great care must be taken that the sun be visible from the point occupied by the photographic objective, and by the equatorial telescope, during the whole time of the transit, and, indeed, a little longer. For this and other purposes, the observers must make sure of the exact local times of all the contacts.

After the site for the station is selected, a survey of the surrounding region must be made to determine the location of the station relatively to neighboring permanent objects. If a large scale map of the region can be obtained, the position of the station may be marked upon it; but if no such map is available, one must be made.

A carefully-written description of the position of the station must also accompany the map. The object of these records is to provide means for relocating the station within one or two hundred yards at any future time.

III.—LAYING OFF GROUND, AND SETTING UP INSTRUMENTS.

The approximate position of the meridian-line, on which are to be placed the three piers for supporting the transit, the photographic objective, and the plate-holder, being determined by compass or otherwise, the next two operations, which may be carried on together, will be the laying down of an exact meridian-line and the erection of a pier for the transit.

As soon as the position of the transit pier is decided, a point should be selected about seven feet east or west of its center, from which to lay off a meridian-line by the theodolite. The latter instrument being placed over this point, a stake should be driven nearly south or north of it, and at a distance of not less than one hundred feet; and then the azimuth of the line joining the instrument and the stake should be found from observations of the sun or stars made on both sides of the meridian. From this line of known azimuth a true meridian-line should next be laid down, and that can be done either with the theodolite, or by setting off a proper offset from the stake. Perhaps the latter is the better method.

The foundation of the transit pier should be three or four feet below the surface of the ground, and, in northern stations, below the reach of frost, if practicable. The last earth at the bottom of the excavation should be carefully removed with a spade in horizontal slices, so as to produce a clean, hard, surface for the footing course to rest upon. It is desirable to prevent the surface earth pressing against the sides of the pier, and for that reason a vacant space one or two feet deep should be left around it—a curb being used to keep back the earth, if necessary. The sides of the pier must face the cardinal points accurately. Above ground, it should measure twenty-one inches from north to south, and twenty-five inches from east to west; below, it may be from three to three and a half feet square. The cap-stone must be twenty-four by twenty-eight inches, and three inches thick. The transit house must be built around the pier after the latter is erected, the floor of the house being placed twenty-nine inches below the top of the pier.

In the northern hemisphere the photographic house will be south, and in the southern hemisphere north, of the transit house. The positions and depths of the holes for the iron piers of the photoheliograph can be readily determined by means of the meridian line and the numbers in TABLE I. The holes may be dug at any time, but the piers cannot be set until the transit instrument has been brought into the meridian and its errors made as small as possible. The lower ends of the piers have thin edges, and to prevent them settling into the ground they should be placed upon large flat stones in the bottoms of the holes. The conditions to be fulfilled in erecting the piers are as follows:

1. The flanged ends of the piers must be uppermost.

2. The larger of the two piers carries the photographic objective, and goes nearest the transit house. Its center must be about fourteen feet from the center of the transit pier.

3. The distance between the centers of the two piers must be as stated in TABLE I.

4. The height of the upper surface of the flange of each pier, or, in other words, the height of its top, must be as stated in TABLE I.

5. The centers of the two piers must be in the plane of the true meridian passing through the transit instrument.

6. The piers must stand perfectly plumb.

7. The screw-holes in the flanges of the piers must be so placed that in each pier the hole nearest the transit house is in the plane of the meridian—that is, in the plane passing through the centers of the piers. The aperture in the side of the plate-holder pier must also be in the meridian, but must face away from the transit house.

The simultaneous fulfillment of so many conditions is troublesome. A convenient way of proceeding will be to tack a lath across the slit in the transit house at a point four feet above the floor, and from it to stretch a cord, perhaps sixty feet long, in the meridian of the transit instrument and horizontally. A strip of wood must also be jammed into the top of each iron pier in such a way that a five-penny nail can be driven into it, and be left projecting an inch, to mark the center of the pier. Then, by sticking pins through the line at the points beneath which the centers of the piers must be located, the latter can be brought very approximately into position. In making the final adjustments, an engineer's level and a theodolite will be required. The engineer's level should be set up about sixty feet from the transit pier, and in such a position that the latter can be seen through the door of the transit house. The theodolite must be mounted behind the transit house, and in the meridian of, but a little higher than, the transit instrument, so that the tops of the iron piers can be seen over the latter. By moving the transit instrument in altitude only, and the theodolite in both altitude and azimuth, the two instruments must be pointed on each other, and the image of the central wires of the transit must be brought into coincidence with the central wires of the theodolite, and then the line of collimation of the latter will describe a plane parallel to the meridian of the former. This suffices for our purpose; but if it is desired to bring the meridians of the two instruments into absolute coincidence, it can be done by shifting the theodolite towards the east or west until the images of the two objectives given by the theodolite eye-piece are seen to be concentric. For that purpose a magnifier is necessary, and care must be taken that the coincidence of wires of the two instruments is left perfect. Thus adjusted, the theodolite will show with great precision when the centers of the piers are in the meridian of the transit instrument; and the engineer's level will show equally exactly when their tops are at the proper height.

Instead of using a theodolite to place the piers in the meridian, the transit instrument itself may be employed, if its objective is covered by a cap having a diametral slit one-fifth of an inch wide. This slit must be placed truly vertical, and then it will be possible to obtain somewhat indistinct vision of any vertical line situated in the meridian of the instrument and having a diameter not less than the width of the slit. If the centers of the piers are marked by twenty-penny nails, instead of five-penny ones, they can be seen through the transit. To guard against error, after a pier has been apparently brought into the meridian, the cap should be twisted through half a revolution, and if that produces any change in the position of the image in the transit, the mean of the two positions will be the true one, and the center of the pier must be adjusted accordingly.

The pier for the photographic objective should first be brought accurately into position, and afterwards the same thing should be done for the plate-holder pier. In adjusting the distance between the two piers a steel tape-line must be used, not a linen one. Nails answer well as wedges for making small changes in the heights of the piers. When all is ready, the piers must be finally fixed by filling the holes around them with masonry laid in cement, or with cement concrete—earth does not give sufficient firmness; and in doing this special care must be taken that they are not accidentally shifted from their true positions. Their interiors should also be filled with concrete to the level of the ground.

The photographic house must be built around the plate-holder pier, the floor of the house being placed exactly three feet ten and three-quarter inches below the upper surface of the flange of the pier.

The cast-iron plates which support the photographic objective and plate-holder are next to be fixed in position. The coffin-shaped plate is to be bolted to the larger pier, its long end being turned toward the photographic house, and at least one washer being placed around each bolt, between the plate and the pier, so as to give the former a solid bearing. The coffin plates are not all alike. The older ones have pipes at the end, to receive the prongs of the piece which supports the objective. These pipes must be turned downward. The newer ones have a planed seat, upon which the bottom of the support for the objective is bolted. This seat must face upward. When the objective-carrier is first mounted upon the coffin plate, the screw, or screws, which hold it should be only lightly set up; but afterwards, when all has been found right, they must be firmly turned home, and the pipes, if there are any, may be filled with plaster or cement. The round cast-iron disc which carries the plate-holder is to be secured to the pier in the photographic house by the proper supporting and binding screws, care being taken that it is turned in the right direction.

To mount the plate-holder, the brass cross must be screwed to the cast-iron disc on top of the plate-holder pier, the tube of the cross passing down through the hole in the disc. The vertical axis of the plate-holder is to be set in this tube, and when the plate-holder is rotated its ends should just graze the raised ends of the cross below it. Milled-headed screws, passing through slots in pieces at the ends of the arms of the cross, are provided for fixing the plate-holder in position, with the reticule plate at right angles to the optical axis of the objective

The structure for carrying the iron measuring-rod and the tube of the photoheliograph should next be erected; and the measuring-rod, but not the tube, must be mounted. The last frame of the structure should be two feet distant from the nearest edge of the coffin-plate, and the position of the measuring-rod must be parallel to, but nine inches above, the optical axis of the photographic objective. For further details, consult section XI.

IV.—MEMORANDA RESPECTING THE PHOTOHELIOGRAPH.

For convenience of reference the measurements required in erecting the horizontal photoheliograph are here recapitulated.

The houses may be set up on stakes 4″ square, driven firmly into the ground. The upper surfaces of the floors should be 7″ or 8″ above the surface of the ground. The distance from the upper surfaces of the floors to the bottoms of the sills is about 3½″.

Size of transit pier: below ground, 3′ or 3′ 6″ square; above ground, 21″x25″. Capstone for ditto, 24″x28″x3″. Top of pier above floor, 29″. Eye-piece of transit above floor, 3′ 9½″.

The iron piers for the photoheliograph are 8′ 0″ long. The larger of the two carries the objective.

Distance from center of transit pier to center of pier for photographic objective, 14′ 0″.

Photographic house: Floor 8½″ lower than floor of transit house. Distance from inner side of wall of house to center of plate-holder pier, 12″. The top of this pier is 9¼″ above top of transit pier, and 3′ 10¾″ above floor of photographic house. Center of plate-holder above floor, 4′ 6″.

In TABLE I, the quantities on each line refer to a single photoheliograph. The number of the objective is given in column A. The distance between the back surface of the objective and the sensitive surface of the photographic plate is given in column B; it being assumed that the thickness of the reticule plate is 0.25 of an inch. The distance of the back surface of the objective from its second principal point is given in column C. The distance between the centers of the piers which carry the objective and plate-holder is given in column D. The height of the top of the objective pier above the top of the transit pier is given in column E. The number of the measuring-rod to be used with each objective is given in column F. The length of each measuring-rod, at 62° Fahrenheit, is given in column G.

TABLE I.

A.	B.	C.	D.	E.	F.	G.
	Inches.	Inch.	Inches.	Inches.		Inches.
1	462.51	0.711	477.6	10.4	VIII	451.491
2	465.08	.682	. .	. .	VII	453.498
3	462.27	.674	476.9	9.4	II	450.437
4	463.33	.718	478.8	10.4	VI	451.946
5	464.79	.538	479.9	10.4	III	453.488
6	472.90	.708	488.5	10.4	I	461.425
7	461.20	.644	476.4	10.4	V	449.485
8	461.30	0.708	476.0	9.4	IV	450.357

The expansion of the measuring-rods may be taken as 0.0000070 of their length for one degree Fahrenheit.

V.—ADJUSTMENTS OF THE PHOTOHELIOGRAPH.

The photoheliograph must fulfill the following conditions:

1. The sensitive surface of the photographic plate must be at the focus of the objective.

2. The line joining the optical center of the object-glass and the cross-lines in the middle of the reticule plate must be in the true meridian, within a fraction of a minute of arc.

3. The same line must be horizontal, within the same limits.

4. The optical axis of the objective must be directed toward the center of the reticule plate.

5. The reticule plate must be perpendicular to the line joining its center and the center of the objective.

6. To let the plumb line hang freely, the sides of the plate-holder must be vertical; and that will be attained by making its top level.

These adjustments are made as follows:

1. By the aid of the measuring-rod, set the coffin-plate so that the distance between the back surface of the objective and the sensitive surface of the photographic plate is as stated in column B of TABLE I. To guard against errors, after the adjustments 1 to 4 have been made, remove the brass plate-holder and use the wooden one to take a number of photographs of the sun at different distances inside and outside the focus. The points at which the small spots on the sun begin to disappear when the plate is too far in, and again when it is too far out, must be noted. The mean of the two positions is the true focus. If, after repeated trials, it differs more than one-quarter of an inch from the point found by measurement, the position of the objective must be changed accordingly.

2. When the photographic objective is in position, point the telescope of the transit instrument at it, and set a bull's-eye lantern behind the center of the reticule-plate. The lines upon the latter will then be visible through the transit, but not very distinctly, because the photographic focus of the photoheliograph differs considerably from its visual focus. If there is any difficulty in seeing and identifying the intersection of the central lines, gum a small triangular bit of paper upon the reticule-plate with one of its angles at the point in question; or rule a little cross with ink, making its lines not more than half an inch long, and taking care that they coincide exactly with the etched lines of the plate. If the azimuth and collimation of the transit are quite right, its middle vertical wire should be on the middle vertical line of the reticule-plate. If it is not found so, the error must be corrected by moving the brass cross which carries the plate-holder.

3. Point the transit so that its middle horizontal wire accurately coincides with the image of the middle horizontal line of the reticule-plate, and clamp it firmly in that position. Then set up a carefully adjusted engineer's level between the transit house and the photographic objective, point it into the latter, and bring its horizontal wire into accurate coincidence with the image of the middle horizontal line of the reticule-plate. Read the bubble of the level, and if it is within six or eight divisions of the

middle of its scale the height of the plate-holder is probably satisfactory. To make sure of this, point the level at the transit, bring its horizontal wire into exact coincidence with the middle horizontal wire of the latter, and again read its bubble. Half the distance traveled by the bubble between the two readings will be the error of level of the center of the reticule-plate.

Probably at the first trial the bubble will run all the way to one end or the other of its tube. If, at each pointing, it runs to the end nearest the photographic house, the reticule-plate is too high; but if to the end nearest the transit house, the reticule-plate is too low. In either case the error must be corrected by changing the elevation of the plate-holder, or by changing the elevation of the coffin-plate, or by both. The height of the plate-holder is controlled by the adjusting-screws of the iron disk supporting it, and the altitude of the coffin-plate may be modified by increasing or diminishing the number of washers under it.

If instead of an engineer's level a level of precision is employed, its telescope must be pointed at the center of the reticule-plate, and its bubble must be read, reversed, and read again. Let the difference of these two readings be A. Then the telescope must be rotated about its optical axis through half a revolution, once more pointed at the center of the reticule-plate, and, as before, the bubble must be read, reversed, and read again. Calling the difference of this last pair of readings B, the error of level of the center of the reticule-plate will be $\frac{1}{4}(A+B)$. The object in rotating the telescope through half a revolution is to eliminate its collimation-error.

4. After the plate-holder is fixed in its true position, adjust the objective by its three supporting-screws so that if a candle in the photographic house is held in the line passing through the centers of the objective and reticule-plate, its three reflections from the objective will also lie in the same line. Instead of a candle, it is sometimes convenient to use a reflector consisting of a card-board disc two or three inches in diameter, with a hole one-quarter of an inch in diameter through its center. In that case, the three images of the hole reflected from the objective must lie in the line in question.

5. Adjust the reticule-plate so that if a candle in the photographic house is held as far as possible from it, and in the line passing through its center and the center of the objective, the reflection of the candle from the reticule-plate will also lie in the same line. Here, again, a card-board reflector may be used instead of a candle. The adjustment is made in altitude by the screws supporting the iron disc which carries the plate-holder, and in azimuth by turning the latter on its vertical axis. When all is right, the screws confining the plate-holder must be firmly turned home.

If this adjustment is correctly made the surfaces of the reticule-plate will be vertical. This may be independently tested in two ways:

(*a*). Set the engineer's level outside the house, at the height of, and near the central line joining the objective and plate-holder, in either direction from the latter, and at such distance from it, not less than 15 or 20 feet, as will be favorable for the observation. Point the level at the plate-holder, turn the latter so that a horizontal line upon the surface of the reticule shall be perpendicular to the line from the level, and adjust the focus of the level so that its objective can be seen by reflection from the reticule-plate. If the plate is vertical, and the level properly adjusted, the horizontal wire of the level will bisect the reflected image of the objective. The latter should return to its position when the plate-holder is turned half-way round on its axis, so that the reflection takes place from the other surface.

(*b*). Adjust the base of the plate-holder so that the bubble of a level set upon its top shall not vary greatly in position when the holder is turned on its axis.

If these two tests cannot be both satisfied within one or two minutes of arc by the same adjustment, the chief should endeavor to ascertain what is wrong, though it may not be advisable for him to try to correct it.

6. The verticality of the sides of the plate-holder is controlled by the supporting screws of the iron disk which carries it. An ordinary carpenter's level suffices to show when the adjustment is correct.

The adjustments from 1 to 6 are necessarily made consecutively, and they must be gone over a second time to make sure that the later ones have not disturbed those first established.

VI.—THE HELIOSTAT.

As the heliostat will presently be needed, it should now be set in front of the objective, upon the coffin-shaped plate, and the three adjustments which it requires should be made. They are as follows: 1. Its main axis must be brought into the plane of the meridian; 2. Its main axis must be set at that inclination which will keep the sun's image most nearly at a constant height upon the reticule plate; 3. The driving-clock must be arranged to rotate the main axis at the proper speed. Extreme accuracy in these adjustments is superfluous, because, in order to obtain freedom from vibration, a form of heliostat has been adopted which can throw the sun's rays only approximately in a constant direction. A convenient way of proceeding, and one which will probably give as good results as any, will be to make the first adjustment by estimation, using a ruler laid against the cube of the main axis to aid the judgment; and then to effect the second and third adjustments by trial.

If more exactness is desired, the first adjustment may be made by setting the mirror at right angles to the main axis of the heliostat, and then setting the latter so that the mirror is also at right angles to the axis of the photographic telescope. The setting of the mirror is accomplished when the direction of a ray reflected from its first surface is not affected by rotating the main axis; but in applying this test care must be taken not to mistake the ray reflected from the second surface for that from the first. Then the main axis is brought into the plane of the meridian, and made horizontal, by setting the heliostat so that it will reflect back upon itself the light from a candle held at the center of the reticule-plate. The proper inclination for the main axis may be computed, and the axis can be set by means of a clinometer; but the rating of the driving-clock can only be effected by trial.

Whenever the azimuth and level of the center of the reticule-plate are determined, the heliostat will have to be removed from the coffin plate; and to save trouble in returning it to its proper place, the points where its feet rest should be marked.

The driving-clock is provided with three pulleys, whose time of revolution may be varied from 37.8 seconds to 42.3 seconds by raising or lowering the pendulum bob. The screw of the heliostat carries two wheels, either of which can be connected by a leather band to any one of the driving-clock pulleys; and by making suitable combinations, the screw can be driven at any desired speed between the limits 58.8 seconds and 115.0 seconds per revolution. This suffices for all localities. Sometimes the pendulum of the driving-clock takes a wabbling motion, moving in an ellipse instead of a circle. When this happens it is generally occasioned by friction at the point of suspension, and a little oil will remedy the difficulty.

VII.—THE EXPOSING SLIDE.

The frame carrying the exposing slide must be screwed to the inner surface of the wall of the photographic house in such a position that the line joining the centers of the objective and reticule-plate passes through the center of the opening in the frame. Upon each end of that surface of the slide which is nearest the objective a target is painted, and whenever the slide is brought into contact with the pieces which limit its motion, one other of these targets covers the aperture in the frame, and is visible to a person standing at the objective. If the image of the sun given by the latter is then centered upon the target, it is intended that it shall also be found centered upon the reticule-plate when the slide is moved across the opening in the frame. To secure this result, the adjustments of the photoheliograph should be completed before the frame is put up, and special pains should be taken to fix it exactly in its right position.

By means of the six milled-headed screws upon the slide, the brass plates can be set so as to give any desired width of slit; but in doing this care must be taken to keep the center of the slit coincident with the center of the opening in the slide, because the automatic key for recording the instant of exposure upon the chronograph is arranged to break when the centers of the openings in the slit and its frame coincide with each other. It is sometimes desirable to see the entire image of the sun upon the reticule-plate, and the slit is arranged to open wide enough for that.

VIII.—THE TUBE.

Experience has shown that for a photoheliograph of thirty-eight and a half feet focus twelve feet of tube is sufficient. For convenience of transportation, that furnished to the parties is slightly conical, and in two-feet lengths packed inside each other. In mounting the tube, four points require attention, namely: 1. The largest end of the tube should pass snugly through the wall of the photographic house and rest against the back of the exposing-slide frame. 2. The centers of the openings in all the diaphragms should be in the straight line joining the centers of the objective and reticule-plate. 3. From the reticule-plate nothing but black surfaces should be visible. The presence of white light risks fogging the photographic plates, and therefore this condition is imperative. To fulfill it, that one of the frames carrying the measuring-rod which is nearest the objective must have its upper part boarded over so as to shut out extraneous light from the tube. Both surfaces of this screen should be colored dead black, and a hole must be cut through it just large enough to permit the free passage of rays from all parts of the objective. 4. It is absolutely necessary that both the tube and the measuring-rod be thoroughly protected from the sun's rays. As there must be an air-space of from six to twelve inches around the tube, the roof or awning covering it should have a depth not less than three and one-quarter feet. Beyond the termination of the tube, the covering for the measuring-rod may be formed of three boards, each eight inches wide, put together so as to form a kind of inverted trough.

IX.—THE PLATE-HOLDER PLUMB-LINE.

Both the chief of party and the chief photographer must give special attention to the plate-holder plumb-line. The wire employed is of gilded brass, having a length of about three feet and a diameter of 0.0025 of an inch. It must be without any bends or kinks, must pass perfectly freely through the axis of the plate-holder, and must be loaded with one-fifth of its breaking weight To secure steadiness, the weight must hang in a vessel of water within the pier, care being taken that the vessel has sufficient size and is so placed as to avoid any risk of the weight resting against its bottom or sides. The upper extremity of the plumb-line is wedged into a brass piece which fits into a socket in the top of the plate-holder, and is provided with an arm for rotating the wire through half a revolution, so as to eliminate the effect of any undetected kinks or bends. Aside from this motion of rotation, the plumb-line should be disturbed as little as possible.

The chief of party must satisfy himself from time to time that the plumb-line does not come into contact with anything in its passage through the opening in the axis of the plate-holder. One way of testing this will be to let the bob swing through a minute arc, and see that the swinging motion of the suspending wire across the face of the reticule plate, as viewed with a magnifying glass, is perfectly regular.

X.—BATTERIES AND ELECTRICAL CONNECTIONS.

The batteries furnished to the parties are of the Daniell's gravity form. To set up a cell, unfold the copper element; place it, together with about two pounds of coarsely-powdered copper sulphate, in the bottom of the glass jar; and lead the insulated copper terminal out over the top of the jar. If the cell is desired for immediate use, fill it to within one and a half inches of the top with water in which a little zinc sulphate has been dissolved; and suspend the zinc element in this solution by hooking it to the top of the jar. If the cell is not required immediately, it is better to fill it with pure water, and then to connect the copper terminal with the zinc. In a few hours it will be in good working order. When using these cells care must be taken that the zinc sulphate solution does not become too strong, that it covers the zinc element, and that there are always some copper sulphate crystals in the bottom of the jar.

No stronger current than that from a single Daniell's cell should ever be passed through a break-circuit chronometer; and as that will not usually suffice for working a chronograph, the chronometer must be joined up in circuit with one cell of battery, a single-point switch, and a repeater of about six ohms resistance. The break-circuit points in the chronometer are very delicate, and to diminish the spark at them the lid of the chronometer box contains a condenser which should be included in the circuit. The chronograph must be joined up in a second circuit, passing through the points of the repeater, and including the observing key at the transit instrument, the automatic key of the exposing slide in the photographic house, and such a number of battery cells as may be necessary. Thus the chronometer circuit will control the chronograph circuit, and by opening the switch in the former, both circuits will be opened. It will be well to arrange the wires in such a way that the automatic key in the photographic house can be cut out when not in use. As a rule, only break-circuit signals will be used, but the observing keys furnished to the parties have a screw at the back, by shifting which they can be converted into make-circuit keys if desired.

XI.—THE MEASURING-ROD.

The most convenient way of supporting the measuring-rod will be to pass it through holes one and one-quarter inches in diameter in boards nailed across the tops of A-shaped frames placed not more than six feet apart. Whatever mode of support is adopted, special care must be taken to see that the rod lies perfectly straight, and that it is parallel to the optical axis of the photographic telescope.

The rod is of wrought-iron gas-pipe, eight-tenths of an inch diameter, in sections five feet long, with Arabic numbers at the joints to show how they go together. The Roman numbers in the middle of each section are the number of the rod. The ends of each section must be carefully cleaned with an oily rag before they are united, and in screwing them together their shoulders must be made to meet snugly. Marks at each joint show approximately the point of stopping. If these marks fail to come together, there is dirt in the joint; but if they pass each other slightly, it only indicates that the screw is worn, which is of no consequence, because the length of the rod depends upon the condition of the shoulders and not upon that of the screws. To avoid straining the rod in putting it together, the first two sections should be united and passed on to the supporting frames nearest the objective; then the third section should be added, and the rod should be pushed nearer the photographic house; and so on till it is all together, and in place. The end inside the photographic house should be at the same distance from the front surface of the reticule plate that the end outside is from the back surface of the objective. After being mounted, the rod should not again be disturbed till the party is about to leave the station. Its outer extremity should be slightly greased to prevent it from rusting, and must be protected from the weather by the tin cover furnished for that purpose.

The measuring-rod is used in connection with the jaw-micrometer for determining the interval between the back surface of the objective and the front surface of the reticule plate. To do this, three thermometers must first be placed upon the rod to ascertain its temperature, one being at its center and one near each end. Then a plumb-line, consisting of a brass wire 0.0032 of an inch in diameter, must be hung over the outer end of the rod, the bob of the line hanging in a vessel of water, and being protected from wind by complete immersion in the fluid. Care must be taken that the wire bends sharply over the end of the rod, and is in actual contact with its front surface. When the plumb-line has come to rest, press the arms of the jaw-micrometer against the margin of the object-glass, taking great care to hold the micrometer horizontally, and by the two rack motions bring the end of the central arm gently into contact with the back surface of the objective, and the jaws into such a position that the plumb-line is between them and in the line joining the centers of the pin-holes. In adjusting the position of the pin-holes relatively to the plumb-line, it will be advantageous to use a magnifier of low power. When all the adjustments are correct, read and record the vernier of the micrometer. After making several such measurements at the objective, pass to the plate-holder and make similar measurements from the front surface of the reticule plate. Each measure should be repeated a number of times by different observers, and each separate result should be recorded with the name of the observer, the temperature of the rod, and any other necessary particulars.

Should the rod be too long, file a vertical notch on each side near one end, loop the plumb-line, and let it hang in these notches.

The distance from the front surface of the reticule plate to the position of the collodion film must also be measured as accurately as possible.

XII.—INSTRUMENTAL ERRORS.

When the adjustments of the photoheliograph designated 1, 4, 5, and 6, in section V, have once been made, it is expected they will remain sufficiently exact, unless purposely disturbed. If, by any chance, either 4 or 5 is found wrong, it must be corrected. The errors of 1, 2, and 3 must be determined at least twice a week, but unless they become large they need not be corrected.

To find the error of the first adjustment, the distance from the back surface of the objective to the front surface of the reticule plate must be measured with the greatest care at times when the temperature is not varying rapidly. Directions for doing this are given in the preceding section.

The error of the second adjustment must be found as follows: Every evening before beginning work with the transit instrument, place its eye-piece at the same side of the stand as the azimuthal adjusting screws, and by means of the latter, bring the middle vertical wire of the transit into exact coincidence with the image of the middle vertical line of the reticule plate. After this, the azimuthal adjustment must remain undisturbed during the night's work. Then make a set of time observations; that is, observe two azimuth stars above the pole, two below the pole, and six or eight time stars, one half the observations of each class being made with clamp east and the other half with clamp west. At the close of the night's work again bring the eye-piece to the same side of the stand with the azimuthal screws, and examine the position of the middle wire relatively to the image of the middle vertical line of the reticule plate. If there is any deviation, its amount must be estimated and recorded, but the azimuth of the transit must not be disturbed.

Upon reducing the time observations the azimuth and collimation constants of the transit will become known. Let them be a and c, and let the azimuth of the center of the reticule plate, counted from the meridian toward the left, be A. Then

$$A = -(a+c)$$

There will be two values of c, one for clamp east and the other for clamp west. The one to be used is that corresponding to the position of the instrument when its middle wire was set upon the center of the reticule plate. If A exceeds one second of time for several nights, the plate-holder must be adjusted by moving it one-thirtieth of an inch for each second of error.

The method of determining the error of the third adjustment has been already described in section V.

XIII.—FITTINGS OF THE PHOTOGRAPHIC HOUSE.

The photographers will examine the photographic house as soon as it is erected, and see that all white light is perfectly excluded. A single crack in the wall, or even an unprotected keyhole may cause irreparable mischief. Such openings are readily detected from the inside, and when found may be stopped up or covered with yellow paper or other suitable material. In full daylight the orange-glass window will admit too much light, and must be covered with orange envelope paper.

The emulsion chest, drying box, and plate boxes are also to be examined, and any cracks or other openings closed up. The drying box may be screwed to battens fixed against the side of the house, or, if more convenient, it may be mounted on legs. To facilitate cleaning, the top of the box lifts off, and the bottom may be removed by taking out a couple of screws.

Close to the left-hand side of the pier carrying the plate-holder a stand large enough to support a chronometer and the blank form for recording the exposure of plates will be required. A shelf long enough to hold two plate-boxes, side by side, will be fixed to the wall of the dark room close to the right-hand side of the pier, and at a convenient height for taking plates from, and returning them to, the boxes.

A screen should be interposed between the plate-holder and the boxes on the shelf, so that if the slide were moved while the boxes were open (which ought never to happen) no light could fall on the plates. That part of the opposite wall which receives the sunlight passing through the plate-holder should be blackened, or covered with dark-colored cloth, so as not to reflect light about the room.

If external objects illuminated by direct sunlight are visible from any part of the plate-holder in any position of the slide, foggy plates and blurred images may be expected, and under circumstances requiring long exposures any light-colored surface, exposed to radiation from the sky may produce similar effects.

An abundant supply of good water is indispensable. For developing dry plates almost any well, spring, or river water may be used, even if it contains rather large quantities of some salts and is not entirely free from organic matter. If it should be necessary to prepare silver baths, water must be distilled if it cannot be otherwise obtained of sufficient purity.

XIV.—CARE OF THE SENSITIVE EMULSION.

The sensitive collodio-bromide emulsion is contained in bottles of orange glass, only partially filled to facilitate efficient shaking. After standing undisturbed for a long time the silver bromide partly subsides to the bottom of the bottle, but it may be perfectly re-emulsified by agitation. By inverting the bottle and looking through its bottom toward the dark-room window, a more or less abundant deposit will be seen, and the shaking should be persevered in until this is entirely broken up and washed away. When this has once been thoroughly effected the bromide will be easily kept in suspension by a little shaking at intervals of a day or two. Collodion vials containing emulsion should always be well shaken and then allowed to stand a few minutes before coating plates. As issued it contains a certain amount of coarse sediment which must be removed by filtration.

The emulsion must not be exposed to white light, for although the bottles containing it are of colored glass they cannot be absolutely relied on to protect it from injury. It is true that some collodion emulsions may be submitted for a short time to the action of weak daylight without material deterioration, but in other cases only foggy images can be obtained after such treatment. Additional caution is requisite with emulsion that has been transferred to collodion vials of colorless glass. The greatest care must also be taken not to contaminate the emulsion by flowing it upon glass that is not perfectly clean, or by putting it into bottles that have been exposed to light with traces of emulsion adhering to them.

XV.—SELECTING AND MARKING GLASS.

The photographic operations will be begun by examining the stock of glass and rejecting all plates that are broken or cracked, not sufficiently flat, with a rough or uneven surface, too large to enter the grooves of the plate-boxes easily, or having any corner so short that it will not rest securely on the pins in the plate-holder of the photoheliograph. A sufficient quantity of the best glass, not less than 204 plates, is next to be selected for the transit plates, and after choosing the best surface for the front, or film side, each plate is to be marked in one corner of the back with a number, beginning with unity and proceeding consecutively upward. This is to be done neatly and legibly with a writing diamond, and to facilitate reference to the finished photographs when stored in plate-boxes the numerals should be so placed as to be upright in the right-hand upper corner of the plate.

XVI.—CLEANING AND ALBUMENIZING GLASS.

Remove the sharp edges with a whetstone, and clean the glass from any gross impurity that may be adhering to it. Old films are best got rid of by soaking for a few hours in a moderately strong solution of concentrated lye, after which they can generally be washed away without much labor; but the surface of the glass may be injured by leaving it too long in such a solution, and especially by allowing the latter to dry upon the plate.

The chromic solution recommended by Mr. M. C. Lea is best adapted to the circumstances of the transit of Venus photographers, as it rapidly oxidizes organic impurities and gives off no vapor injurious to instruments.

Solution for Cleaning Glass.

Bichromate of potash -	4 ounces.
Sulphuric acid - - -	6 fluid ounces.
Water - - - - - - -	50 fluid ounces.

Put the bichromate of potash into a two-quart bottle and pour in the water. Then add (out of doors) the sulphuric acid, a little at a time, shaking the bottle well and allowing it to stand a few minutes after each addition. It will become very hot and give off a little corrosive vapor, which, however, soon disappears. If too much acid is added at once the bottle will probably be broken by the heat. When the bichromate of potash is all dissolved, and the solution has cooled, it is ready for use. Pour it into a large rubber pan, and immerse, one at a time, as many plates as the solution will cover. If any bubbles are allowed to remain between the plates they will prevent the solution from acting on the surfaces in contact with them. The glass should remain in the chromic solution through one night at least, and a still longer time may be desirable, but it ought not to exceed a week, or thereabout.

Remove the plates from the cleaning solution and put them into a pan or bucket of clean water. The solution may be repeatedly used; it will not injure the skin beyond causing a slight stain and a rather disagreeable odor, but it is very destructive to clothing. Renew the water in the bucket, and separate the plates from each other until the yellow fluid adhering to them is entirely washed away; then refill the bucket so as to leave them entirely covered with clean water.

The plates are now to be taken one at a time from the bucket and rubbed with the fingers, or with a clean cloth, on both sides and around all the edges while the water from the tap flows on them. After a final rinse they will be ready for albumenizing.

Albumen Solution

White of egg	- - -	1 fluid ounce.
Water	- - - - -	16 fluid ounces.
Strong ammonia	- -	15 minims.

Put the white of egg into a clean bottle of convenient size together with a few pieces of broken glass, shake it vigorously until the albumen is thoroughly "beaten," and allow it to stand undisturbed for several hours. Then add the water and ammonia, and shake just enough to mix the contents of the bottle, after which it should again stand for some time before being filtered for use. If tolerably fresh eggs cannot be obtained, 100 grains of dried albumen may be taken as the equivalent of 1 fluid ounce of white of egg, but the latter is much to be preferred.

Filter the albumen solution into an 8-ounce graduate until it is two-thirds filled, keeping the neck of the funnel under the surface of the filtered albumen to avoid bubbles. The few bubbles that unavoidably form may be removed with a wisp of clean paper.

When a plate has been washed and rinsed as already described, observe by the mark on the back which is the front side, and flow it with the albumen solution. After draining the plate for a few seconds, flow it a second time precisely as before and set it on a rack to dry, always keeping the same corner downward, and never touching the front surface or the uppermost edges. The plates will be apparently dry in the course of an hour or two after albumenizing, but the albumen should be allowed to become thoroughly desiccated and hardened by keeping in a dry place, properly protected against dust, for several days if possible. If coated with emulsion too soon after albumenizing, the films will be more liable to blister and rise from the glass during development, a misfortune to be avoided by the exercise of every possible precaution. The albumenized plates are finally to be examined, and any imperfect ones set aside to be cleaned again.

As the permanent marks on the plates will scarcely be visible in the dark room, write the number of each one with a blue pencil, or with ink, in large and plain figures on a gummed label, and attach it to the back of the corresponding plate in such position that when the latter is put into a plate-box the permanent mark will be seen in the upper right-hand corner, and the number on the label in the upper left-hand corner of the plate. Re-examine them carefully to insure that the two numbers on each plate are identical, and, if found so, store them in plate-boxes for use as required.

XVII.—COATING PLATES.

As the plates are necessarily exposed for a considerable time to whatever light may be in the dark room while they are being coated, it is necessary to proceed with caution. But by operating near the window while the emulsion vials, and the rack holding the plates already coated, are protected from direct light by interposing screens, it is possible to work with both ease and safety. The outer door must, of course, be locked. In very warm weather it is more comfortable to coat plates at night with the door and window open if there are no gas lamps or other dangerous lights outside. It will be safe to use naked candles if they are so screened that no direct light from them or from any nearly white object strongly illuminated by them can fall on the plates or the emulsion. Light from gas or coal-oil lamps is more actinic than that of candles, and must be used with caution if at all. Orange-glass lanterns ought to be quite safe if candles are used in them, but it must not be taken for granted that they are so.

Set one of the racks from the drying box where no direct light from the window can fall on it, and have at hand a wide camel's-hair brush, and a bottle containing a mixture of two volumes of ether and one volume of alcohol for thinning the emulsion. Begin by thoroughly shaking the bottle of emulsion it is proposed to use; then insert a tuft of filtering cotton in the throat of a perfectly clean emulsion filter and moisten it with a little of the thinning mixture. Set the filter in a twelve-ounce collodion vial, pour in emulsion from the bottle until it is nearly full, put on the cover, and set an orange bell-glass over the filter and vial to diminish evaporation and prevent the access of light. If the tuft of cotton is too large and too closely packed, filtration will be slow and tedious; if not properly inserted it will permit the passage of small particles of sediment, &c. The emulsion should pass through in a rapid succession of large drops, about one per second. It may run in a thin stream at first, as its passage will be slower when the cotton is fully saturated with emulsion. Replenish the filter from the emulsion bottle before it becomes empty, and transfer it to another collodion vial when the first one is two-thirds full. While plates are being coated from one vial the other will be filling, and so on, using them alternately.

Take a plate from the plate-box, and, holding it near the window, see if the albumenized surface is free from fibers and particles of dust. Such substances may be carefully removed with the brush, but actual brushing will leave marks on the albumen. Holding the plate by the corner that was marked with the writing-diamond, coat it with emulsion, precisely as if it were collodion, and, as soon as the film is set, put the plate in the rack. As emulsion is, under ordinary circumstances, rather less fluid than collodion it is possible that operators who are accustomed to use thin collodion, and coat their plates very deliberately, may experience some difficulty in obtaining a uniform film. Pour on a rather liberal dose of emulsion and cover the plate quickly; then incline the plate but little, so as to pour off very slowly, and impart to it whatever motion may be necessary to prevent the formation of lines. The precautions usual with careful operators to prevent particles of dried emulsion on the lip of the vial from falling upon the plate must, of course, be observed. It is sometimes recommended to pour from one vial and to drain the plate into another, so that emulsion once poured out may be filtered before it is used again; but this mode of operating is inconvenient, and will not be necessary unless the atmosphere of the dark room is charged with dust. The corner by which the plate was held while coating with emulsion is, of course, left uncovered; by looking toward the window through this clear space the permanently marked number of the plate may be read in the dark room, though with some difficulty. When the emulsion becomes too thick to flow well (or sooner if particles of foreign matter are seen in it) add as much of the mixture of ether and alcohol as may be required to bring it to the proper consistency, pour the whole into the emulsion bottle, and shake it until well mixed. Then transfer the filter to the empty vial, and begin using the full one. The filter must not be allowed to become empty. If the vial containing it is getting too nearly full it may be set in the emulsion bottle. Do not dilute the emulsion unnecessarily by using the thinning mixture too freely.

When the rack is full of plates remove it to the highest unoccupied position in the drying-box, and avoid all further risk of accident to them by closing and bolting the doors. The box will contain 120 plates, but it is better to make a smaller number at one operation, filling only every second or third groove of each rack. When a sufficient number of plates are prepared return the bottle and vials to the emulsion chest, and wash the filter perfectly clean before the adhering emulsion becomes dry and hard.

Plates freely exposed to the air of the dark room would be dry in an hour or thereabout; in the drying-box a longer time will be required, and several hours at least should be allowed. At night the top and bottom of the box may be taken off. When quite dry the plates are to be put in plate-boxes that are clean and free from dust, in the order of their numbers, with the films toward the back or hinge side of the boxes, the numbered corners uppermost, and the lowest numbers in front. Wrap each box in thick paper, secure it with stout twine, and mark plainly on the package the numbers of the plates it contains.

With each batch of plates prepared for observing the transit at least two test-plates are to be made, one near the beginning and one near the end of the operation, using for that purpose some of the glass not selected for the transit work. The test-plates are to be dried with the others and afterward exposed and developed. If they prove to be good the rest of the lot is likely to be equally so.

XVIII.—EXPOSURE OF PLATES IN THE PHOTOHELIOGRAPH.

The sun's image, as seen on the reticule-plate of the photoheliograph, generally has an irregular vibrating motion in different directions, arising from various causes. As the exposure of different parts of the plate lying in the direction of motion of the exposing slide is not simultaneous but successive, any movement of the image as a whole will produce a distortion in the resulting photograph symmetrical with respect to its vertical diameter, and inversely proportional to the velocity of the slide. Moreover, the limb itself is in a state of constant and rapid local agitation, which in some conditions of the atmosphere is so exaggerated as to produce the boiling or flaming appearance familiar to all observers. It results from this that, quite apart from any distinctively photographic effect, the longer the exposure the larger the photograph will be, and that if the motion of the slide is not uniform the limb on the side where the velocity was least will be extended more than the other. So brief is the time of exposure that these effects are indeed minute, but it cannot be assumed that they are in all cases inappreciable. It follows, therefore, that a given exposure is more advantageously made with a wide opening of the slit and a rapid motion of the slide than with a narrow opening and a slow motion, and that the velocity should be in all cases as nearly uniform as possible.

It is expected that the chief astronomer will himself expose the plates on the day of the transit, or, at least, that he will supervise the manipulation of any person to whom this duty is delegated, and see that such assistant has the requisite instruction and previous practice. The movement of the slide should be as rapid as can be given with ease and uniformity, retaining control of it throughout, and avoiding any approach to violence. Toward the end of its course the motion should be slackened so as not to endanger the stops, but it should continue until the slide rests against them. As the regulation of exposure depends entirely on the uniformity of this movement, it should be practiced until a fixed habit is acquired. It is of course important that there should be no great difference in velocity, whether the motion is from east to west or from west to east. To increase the exposure, widen the slit by separating the sliding plates; to diminish it, bring them nearer to each other; always setting them so that the center of the slit shall be in line with the middle pair of screws. The milled nuts must be screwed up so as to clamp the plates securely without using too much force.

In exposure considerable latitude is allowable; indeed the appearance of the sun's image is so similar with very different exposures that the real importance of this element is liable to be underrated. The planet requires less exposure than the sun's limb, but good definition of the latter is the principal end to be attained. If with chemicals in good order and proper development the image comes out reluctantly and remains very thin, or if there is any material falling off in density near the sun's limb, the exposure is too short. To find the correct exposure, begin with one known to be sufficient, and gradually lessen it until signs of under-exposure just begin to appear. If the image is distorted, or looks as if the plate-frame were out of focus, the defect is most probably due to flexure of the mirror. The slightest tension arising from improper mounting, either of lens or mirror, will make itself apparent in this way.

XIX.—THE DEVELOPMENT.

The water used for washing the plates before development, and the developer itself, should have a temperature of at least 60° Fahr.; 90° to 100° is still better. If the weather at any of the northern stations should be cold, it will be well to have a small supply of warm water at hand for these purposes.

The following solutions will be required:

Alcohol and tannin.

Tannin - - - - - - -	20 grains.
Strong alcohol - - -	1 fluid ounce.
Water - - - - - - -	1 fluid ounce.

Pyrogallic solution.

Pyrogallic acid - - -	3 grains.
Water - - - - - - -	1 fluid ounce.

This solution is decomposed by keeping, and only so much must be made at one time as can be used immediately.

Dilute ammonia.

Strong ammonia - -	30 minims.
Water - - - - - - -	1 fluid ounce.

Bromide solution.

Bromide of potassium -	20 grains.
Water - - - - - - -	1 fluid ounce.

To these may be added:

Alkaline citrate solution.

Citrate of ammonia - -	30 grains.
Strong ammonia - - -	30 minims.
Water - - - - - - -	1 fluid ounce.

The dilute ammonia, bromide, and alkaline citrate are to be transferred for use to dropping-bottles, so conspicuously labeled that they can be easily distinguished from each other in the dark-room. It must be borne in mind that a drop from one of the tubes is much smaller than one from the lip of a bottle.

Having put one fluid ounce of pyrogallic solution into one of the small, wide-mouthed bottles issued as developing glasses, begin by treating the film with alcohol and tannin. One principal object of this application is to harden the substratum of albumen. The solution should therefore be flowed back and forth over the plate for at least a minute, and be returned to the bottle when the film is thoroughly saturated. The manipulator is next to be wetted and applied to the back of the plate unless the operator, fearless of stained fingers, prefers to dispense with it. Wash the plate under the tap, or with warm water if necessary, until the water flows smoothly over the film. Then add two drops of bromide solution and two drops of dilute ammonia to the pyrogallic solution in the developing glass and apply it to the plate, keeping it in gentle motion over the film to promote equal development. The image should appear quickly and gradually increase in strength. Subsequent additions of dilute ammonia are to be made, a couple of drops at a time, as the appearance of the plate may indicate, accompanying every alternate addition with an equal quantity of bromide.

If it is preferred to use the alkaline citrate, the developer is to be prepared at first as given above, and the subsequent additions will be of the alkaline citrate solution only. This treatment has given excellent results in some cases and is provisionally recommended.

The formula given above is offered as a starting point for such modifications as circumstances may require, and not as an absolute standard of universal application. The character of the image sought, the age and quality of the emulsion, etc., are varying conditions which render impracticable the adoption of any rigid rules. The end in view is, by means of a developer strong in pyrogallic acid and weak in ammonia to bring out an image of equal density throughout, while the rest of the plate is kept clean by a sufficient quantity of bromide, or of bromide and citrate of ammonia. A greater strength of pyrogallic acid than that prescribed can hardly be required, but this solution may sometimes be advantageously diluted. If the image come out slowly it must be allowed to take its time, and not be forced with too much ammonia. It is scarcely possible to produce dense fog, but a veiled image is usually the result of an excess of ammonia Operators accustomed to the development of gelatine plates must be especially cautious in this respect.

The finished photographs must belong to one of two classes. It is not possible in the case of the sun to obtain an outline as sharp and distinct as in photographs of the moon or of terrestrial objects. But the nearest possible approach to such a definite line is precisely what will most facilitate measurement of the plates, and this must be sought as being of much greater importance than the attainment of any special standard of density. An image that is dull and blurred, when held over a black surface and seen as a positive by reflected light, and that is thin and hazy when viewed as a negative by transmitted light, will be almost worthless, while one bright and clear as seen in either one of the two ways will be valuable. If, therefore, the operator finds it easy to produce a sharp and clear image of the ambrotype variety he may do so, taking care, of course, not to discontinue the development until quite certain that it is equal all around. But if there is from any cause a tendency to discoloration of the film, giving a dull appearance by reflected light, a greater degree of density will be requisite. A slight veiling, even, is not very injurious if the image is clear and strong by transmitted light. No effort should be wasted in striving to attain an unnecessary degree of density, for, although it can hardly be too great, a very moderate density will suffice.

XX.—FIXING AND VARNISHING.

As soon as development is complete wash off all traces of the developer and fix with a weak solution of hyposulphite of soda. Cyanide of potassium must not be used.

Fixing solution:

Hyposulphite of soda, - - - -	½ oz. to 1 oz.
Water, - - - - - - - - - -	16 fluid ounces.

As the silver bromide dissolves rapidly, it is most convenient and safest to pour a little of the fixing solution on the plate, flow it about until the film is clear, and finally dismiss it into the sink. Then wash the plate thoroughly and set it in a rack to dry. After the lapse of sufficient time, several hours at least, varnish in the usual manner.

XXI.—BLISTERING AND LIFTING OF THE FILM.

If the film separates from the glass, or if small blisters form near the sun's limb, the planet, or the plumb-line, the plate is worthless, and no precaution must be neglected that can tend to prevent so great a misfortune. A substratum of albumen that is too thick, such as would be obtained by using a solution materially stronger than that of the formula given above, may be imperfectly coagulated by the alcohol and tannin, and thus aggravate the evil it is designed to prevent. If the directions already given for drying the albumenized plates thoroughly, and for saturating the film with the solution of alcohol and tannin, are followed, it is probable that no trouble will be experienced; but should a tendency to this defect manifest itself during the preliminary practice, special caution will be necessary in conducting the development of the transit plates. Too much ammonia will act on the substratum and must be avoided. The development must be stopped as soon as the least allowable density is reached, and the plate must be fixed by pouring on the hyposulphite solution, and not in a pan.

XXII.—SPOTS AND OTHER DEFECTS.

Small circular transparent spots may appear on the sun's disk, which, if numerous and of a certain size, might resemble the image of Venus and cause time to be lost in measuring the plates. The emulsion furnished is remarkably free from any tendency to produce these spots. If they appear it will be from one of two causes: 1. Particles of foreign matter in the emulsion; 2. Particles of dust that have settled on the plate after coating, especially if charged with chemical substances, such as might arise from solution of bichromate of potash spilled on the floor of the dark-room. The former cause may be removed by properly filtering the emulsion; the latter must be avoided by cleanliness and greater general care.

Certain other defects, such as pin-holes, crapy lines, &c., do not materially detract from the value of the plate, but every operator who cares for his reputation will nevertheless seek to avoid them.

XXIII.—PREPARATORY PRACTICE.

To familiarize themselves with all the details of their work and with the materials they are to use, the photographers will begin to prepare, expose, and develop plates, in accordance with the foregoing instructions, as soon as possible after arriving at their station, and will continue such exercise until the chief of the party is satisfied that they can produce solar photographs of satisfactory quality with ease and certainty. They will avoid any unnecessary expenditure of materials, and will take care that a sufficient supply of everything is reserved for the operations of the transit day. If the bottles of emulsion are labeled with different letters it signifies that pyroxylines of slightly different character have been used. Test the contents of each bottle, and if notable differences of quality are found to exist among them, reserve the best for the transit plates, or mix the various kinds judiciously, as may appear to be preferable.

It has been already remarked that the person who is to expose plates during the transit must acquire a fixed habit of manipulating the exposing slide, and that unless an approximately uniform motion can be thus obtained there will be no means of regulating the exposure. Having secured a tolerably uniform action of the slide by whatever practice may be requisite, proceed by trial according to the instructions given for ascertaining the correct exposure, to find the proper opening of the slit when the sky is quite clear and the atmosphere in the most favorable state. This will be the least opening that can be used at any time, and the one with which the observation of the transit will be commenced if the weather should be good.

If the sun is obscured by clouds so as to be visible for a few minutes only during the transit, it will be necessary to work as rapidly as possible. The manual of operations prescribed for the observation of the transit will permit plates to be exposed at intervals of only a few seconds if every one is perfectly familiar with his duties. In order that each may be prepared to perform his part of the work promptly, the whole party must be drilled from time to time, going through with all the details of making the record, &c., except that plain glass will be used instead of sensitive plates, and there will, of course, be no development.

XXIV.—PREPARATION FOR THE TRANSIT.

When the photographers have become sufficiently familiar with the process they are to use, they will begin to prepare a stock of dry-plates to be used in observing the transit. Eighteen plate-boxes, capable of holding twelve plates each, are supplied to each party. Seventeen of these are to be filled with dry-plates, leaving one box empty. The plates are to be arranged in the boxes in the order of their numbers, as already directed, and the boxes must be so marked that the plates can be exposed in consecutive order. The remaining glass should be cleaned and albumenized, to be used with wet emulsion in case of emergency, and a sufficient quantity of the developing solutions for fifty or more plates must be provided

Everything belonging to the photoheliograph must be in correct adjustment and in good working order, especially the clock-work of the heliostat, which must be so well regulated that it can be left to itself for several minutes without allowing the sun's image to get too far from the center of the plate. See that the mirror, lens, and reticule-plate are perfectly clean, and remove any dust that may adhere to the last-named by wiping it with chamois leather. If artificial light is required for reading the chronometer and making the record, as it probably will be, an orange-glass lantern must be used.

XXV.—PHOTOGRAPHING THE TRANSIT.

Photographs are to be taken only while Venus is completely within the limb of the sun. When the chief astronomer decides that the planet has progressed sufficiently far upon the sun's disk, the automatic break-circuit key of the exposing slide will be put in circuit with the chronograph, that instrument will be started, the members of the party will repair to their respective stations, and, after locking the outer door of the photographic house, the exposure of plates will begin. The services of four persons will be required; if the party consists of but four, their duties will be as provided in what follows:

The assistant astronomer will be stationed at the heliostat, where he will watch the image of the sun on the target of the exposing slide, and keep them nearly concentric by an occasional movement of the tangent screws. The image must never be allowed to get so far from the center as to partly uncover the black disc of the target. He will also note the condition of the sky, and give prompt warning to those in the photographic house when the sun is obscured by clouds, and when it reappears. He will occasionally see that the chronograph is working properly, and give notice when it must be stopped to renew the paper. And finally, he will read the barometer and thermometer as directed in another part of these instructions.

The chief astronomer will make the exposures and keep the record in the following form:

RECORD OF PLATES EXPOSED DURING THE TRANSIT OF VENUS, DECEMBER 6, 1882

At.... .... ; *Chronometer*..................

Plate exposed.	Time of exposure by—		Plumb-line pointer.	Slide moved.	Temp. Fahr.	Remarks.
	Chronometer.	Chronograph.				
No.	*h. m. s.*	*h. m. s.*			°	

When the number of a plate is called he will enter it in the first column, and, taking the time from the chronometer, he will make the exposure at some beat of the latter, and, after giving the chronograph signal, or "rattle," with the break-circuit key, he will enter the chronometer time of exposure in the second column. The time recorded by the chronograph will be read off, and filled in, subsequently.

In the column headed "plumb-line pointer" he will write E. or W., as the case may be. The pointer should be frequently reversed, but if the change is made after the exposure of every plate, the plumb-line will probably never be quite at rest. A much better way is to expose the plates in groups of six, the plates of a group following each other in rapid succession. Then reverse the pointer and give the plumb-line time to come to rest before exposing the next group of plates.

In the column headed "Slide moved" write E. or W., according to the direction of that motion The movement should be alternately eastward and westward, and the slide must always be left resting against the stops that limit its course.

Record the temperature of the photographic house in its proper column at intervals of half an hour, or more frequently if the change is rapid.

In the column for remarks any peculiarity of the plates, of the exposure given, or of atmospheric conditions, and any other circumstance likely to affect the result, should be noted.

When the chief astronomer desires a pause in the work to follow the exposure of any plate he will notify the photographer who changes the plates of his intention before giving the exposure, so as to avoid unnecessary handling of the plates.

When a plate has been developed he will examine it, and, with the advice of the photographers, decide whether any change in the opening of the slit is desirable.

One of the photographers will put the plates into the plate-frame, and remove them after their exposure. He will commence operations by placing the empty plate-box on the right-hand end of the shelf erected for that purpose, and the box containing the plates that bear the lowest numbers of the series, beginning with No. 1, at the left-hand end of the shelf. When directed to proceed he will open the left-hand box, take out the nearest plate, which should, of course, be No. 1, carry it to the plate-frame, keeping the same edge of the plate uppermost, and carefully avoiding any contact with the plumb-line. After securing the plate with the curved spring he will close the plate-box, and then call the number of the plate, reading it from the label, which will be in the upper left-hand corner of the plate-frame. He will then watch the back of the plate closely to see that the sun's image is not too near the edge of the plate. If the distance should be less than about an inch he will so report to the chief astronomer.

When the image appears for an instant on the plate he will open the right-hand box, take the plate from the plate-frame, carry it to the farthest groove in the box, and then close the box. Without waiting for orders he will then open the left-hand box, take out the nearest plate as before, and so on; always keeping the back of the plate toward himself, and the numbers uppermost, and always replacing the plate in the farthest unoccupied groove of the right-hand box.

When the right-hand box is full the other will be empty; the full box must then have a gummed label pasted over the hook in front, so that it cannot be easily opened, and must be put in some place specially designated for the reception of exposed plates. Then remove the empty box to the right-hand end of the shelf, place the next box of the series to the left of it as before, and so proceed until all the plates are exposed. To avoid mistakes, the boxes should be arranged beforehand so that they will be taken up in consecutive order.

The other photographer will develop plates during the whole time of the transit, beginning with the one first exposed. As each plate is fixed and washed he will examine it carefully to see if the exposure is correct, and will call the attention of the chief astronomer to any alteration that may be required. He will then develop another plate, always taking the one last exposed. The grooves in the boxes belonging to plates taken out for development are to be left vacant, and not filled by other plates.

If the sky is clear the groups of plates exposed should be equally distributed over the whole time of the transit; but if it is probable that the entire transit will not be seen, a considerable number of photographs should be secured at once, reserving some plates to be used if the weather should prove better than was anticipated. If the sun is visible at intervals between passing clouds, every one must be at his station to take instant advantage of every opportunity that may offer.

The sun may be partially obscured by thin clouds or by a hazy atmosphere, so as to require very long exposures. After the slit has been opened as widely as possible the exposure can be still further increased by a slower movement of the slide, but good results can hardly be expected under such circumstances.

XXVI.—DEVELOPMENT AND PACKING OF TRANSIT PLATES.

As soon after the transit as possible the photographers will begin to develop the transit plates, and will continue that work without unnecessary intermission until it is completed. After drying and varnishing the plates they will be put in the plate-boxes, and kept from shaking about by small rolls of Joseph paper, long enough to reach crosswise over the tops of the plates, and just large enough to hold all the plates firmly, without too much force, when pressed down by the lid of the box. Two such rolls will be put in each box. The boxes are then to be covered with strong paper and tied with stout twine.

In separating the plates into two or more lots, to be forwarded at different times to Washington, the plates of each lot should be selected so as to include all periods of the transit. If there are only two lots, one should contain all the even-numbered plates, and the other all the odd-numbered ones.

XXVII.—WET EMULSION PLATES.

Wet plates may be prepared with emulsion if any accident should cause the loss of a great part or all of the dry-plates when it is too late to replace them. A glass plate cleaned, albumenized, and coated with emulsion, as already directed, is to be immersed in clean water contained in a pan or dipping-bath as soon as the film is set. When the water flows smoothly over the film, as the plate is lifted, the exposure may be made, but the plate may remain in the water for any reasonable length of time without detriment. Such plates are developed precisely like dry ones, omitting the preliminary treatment with alcohol and tannin. They develop more rapidly than dry-plates made from the same emulsion.

XXVIII.—BATH WET PLATES.

Collodion shrinks greatly in drying, but when once dry it swells but little if wetted either with alcohol or water. A film that has been dried before it is exposed is to be preferred, therefore, to one that is exposed while wet, for photographs that are to be accurately measured. And dry-plates can be exposed so rapidly in the photoheliograph that if the sun should be visible for a short time only during the transit, a most important advantage would be gained by employing them. For these and other reasons, it is expected that they will be used. But if from accidental loss of materials, from lack of experience, or from any other cause, the photographers are unable to prepare and develop emulsion dry-plates successfully, they will have recourse to the usual bath process. It must be definitely decided in advance which process will be used, and preparations must be made for that one only.

If a resort to the bath wet process is deemed advisable, the services of at least one additional photographer must be secured if possible. With three or four photographers it will probably be best to have the chief photographer collodionize all the plates and immerse them in the baths, keeping his hands clean. The other photographers will withdraw the plates from the baths and drain them, put them in the plate-frame, and call their numbers. After exposure they will remove the plates from the plate-frame, develop, fix, and wash them, and, finally, put them in the drying racks. Each photographer will go through the whole course of those manipulations with every plate he takes from the bath, and the different operators will follow each other as rapidly as the limited accommodations of the photographic house will permit.

The best collodion is one that gives a rather hard and patchy negative, for softness, and correct rendering of light and shade, are rather to be avoided than otherwise. The following formula is recommended:

Bromo-iodized collodion.

Alcohol - - - - - -	10 fluid ounces.
Ether - - - - - - -	10 fluid ounces.
Iodide ammonium - -	40 grains.
Iodide cadmium - - -	60 grains.
Bromide ammonium - -	20 grains.

At least three silver baths will be required. They should contain 40 grains of nitrate of silver to the ounce of water, and enough nitric acid to redden blue litmus paper slowly. On removing the plates from the bath drain them as thoroughly as is consistent with rapid work, and wipe their backs. Develop with:

Developer.

Protosulphate of iron - -	1 ounce.
Acetic acid No. 8 - - -	1½ fluid ounces.
Water - - - - - - - -	20 fluid ounces.

These proportions may be varied, however, if it is found advisable to change them. Fix with solution of cyanide of potassium of such strength as to clear the film rather quickly.

The instructions already given for the manipulation of dry-plates will be followed so far as they are applicable. If bath wet plates have been exposed in the photoheliograph, the plate-frame must be thoroughly cleansed from all traces of nitrate of silver before dry-plates are put into it.

XXIX.—GENERAL PRECAUTIONS.

Photographers who are accustomed to the use of dry-plates will be careful from habits already formed, but those who have practiced only the usual wet process must be very cautious indeed to avoid the loss of plates by accidental exposure to light.

Plate-boxes must be opened only to put in or to take out plates, and must be closed again as soon as possible. The drying-box must never be allowed to stand with open doors to avoid the inconvenience of opening and closing them frequently.

Emulsion bottles and vials must be replaced in the emulsion-chest immediately after using them, even if they will soon be wanted again. The lid of the chest should be secured by a strap or otherwise, so that it cannot be left open. The chest must be kept locked, with the key in some specially designated place and not in the key-hole.

When filtering emulsion, and while making or exposing plates, the outside door of the house must invariably be locked.

And, finally, the various manipulations that have been described in these instructions must be conducted with constant and scrupulous regard to cleanliness. It is only by conscientious attention to details like the foregoing, which are by no means trivial, that successful results can be confidently anticipated.

XXX.—THE CHRONOGRAPH.

The speed of the chronograph is governed by a vibrating spring whose normal rate of motion is one hundred and thirty-two vibrations per second. In regulating it, the time of revolution of the cylinder must be made correct within about two per centum by moving the sliding weight near the root of the spring, and then the final adjustment can be effected while the instrument is running by slightly loosening or tightening the capstan-headed screw confining the cheeks between which the spring is held.

The speed of the train is so great that to avoid detrimental friction all the pivots must be frequently oiled, but especially the escape-wheel pivot, and those near it. Weights of one hundred, fifty, twenty-five, and twenty-five pounds are furnished with the instrument, but in ordinary summer weather one hundred pounds drives it well. In winter, a little more may be needed. The weight should have space to fall three feet. This suffices to run the instrument two hours, and if it is wound when a fresh sheet of paper is put on the cylinder, it will not require winding again till the paper is changed.

XXXI.—TIME OBSERVATIONS AND CHRONOMETER COMPARISONS.

Should the station not be in telegraphic communication with a fixed observatory from which local time is received, two azimuth stars above the pole, two below the pole, and six or eight time stars should be observed with the transit instrument on every night when it is practicable. One-half the observations of each class should be made with clamp east, the other half with clamp west. Should the observer be able to get his local time from a fixed observatory, his own determinations may be omitted when not necessary to the success of the expedition. They must, however, be carefully attended to, so far as may be required, either for the determination of his own longitude, or for comparing his local time with that of other parties in the neighborhood. In any case, enough observations must be made to determine the azimuth of the photoheliograph and detect any changes that may occur in it.

All chronometers at the station must be compared daily, when they are wound, unless the local time and longitude are so well determined that no interest attaches to their running. It will sometimes be necessary to carry one of them about, but the others should never be moved when it can be avoided. Every care should be taken to keep them at as uniform a temperature as possible, and the degree of heat to which they are exposed should be noted and recorded three or four times a day.

XXXII.—EXCHANGE OF TIME WITH OTHER PARTIES.

Should any opportunity offer for the comparison of local time or chronometers with parties from other countries, it must be improved. In such case, the observer must be careful to keep a complete copy of the comparison, and to assure himself that he has all the data necessary for determining the difference of longitude between the stations compared.

XXXIII.—LATITUDE AND LONGITUDE OF STATION.

The latitude of the station must be determined with the meridian instrument, used as a zenith telescope, and not less than thirty-six observations should be made upon at least twelve pairs of carefully-selected stars.

Special attention must be paid to getting the true longitude of the station, but the best method of doing this will depend upon circumstances. If the station is in a region covered by an accurate trigonometrical survey, or if it is in telegraphic communication with a fixed observatory, the determination of its longitude will be comparatively easy. In any case, the observer must be on his guard against depending upon a single result. If accurately known trigonometrical points are available, the position of the station must not be determined from a single one of them, but from at least three, whenever possible. If telegraphic signals are exchanged with a fixed observatory, the exchange should be continued through not less than three evenings. At places where neither the trigonometrical nor the telegraphic method is available, recourse must be had to occultations and moon culminations. In observing the latter, care should be taken that the number of observations before and after full moon are nearly equal, and that in each class about as many observations are made by the assistant astronomer as by the chief of party. Instructions respecting occultations are given in section XXXV.

XXXIV.—THE EQUATORIAL TELESCOPE.

At stations where it is necessary to observe occultations, the mounting of the equatorial must be commenced as soon as possible, taking precedence of that of the photographic piers. The site selected must be such that the instrument commands a good view of the eastern and western sky, to within five degrees of the horizon if practicable.

Caution.—The shade glasses supplied with the double-image micrometer are so constructed that they can be employed tolerably safely upon a bright sun with the full aperture of the telescope, but as a matter of precaution, they should be warmed a little before using them, and the telescope should never be left pointed at the sun a moment longer than is necessary. With the shades supplied for the Airy-Huygenian eye-pieces it is quite otherwise. If the sun's rays from the full aperture of the telescope are allowed to pass through one of them with undiminished force, it will split at once, to the great danger of the observer's eye. For that reason they must never be used apart from the Herschel solar prism.

XXXV.—OCCULTATIONS.

At stations whose longitude is not otherwise determined, all visible occultations of stars by the moon which occur during the stay of the party, must be carefully observed. To facilitate this work, the instants of the emersions which happen after the full moon may be computed in advance.

From the time the new moon first becomes visible until her full, she is to be carefully watched with the telescope to see what stars will be occulted. These can be recognized from thirty to sixty minutes beforehand by remembering that the course of the moon is nearly at right angles with the line joining her cusps, and that she moves nearly her own diameter in an hour. Whenever there is a chance of seeing an occultation, a map of the relative positions of the moon and the stars in its neighborhood must be made; and if the occultation is actually observed, the exact point of the moon's limb at which the star disappeared must be noted on the sketch. Nothing must be recorded as an immersion or emersion except the actual sudden and distinct disappearance or re-appearance of the star at the moon's limb. If the star is lost in the moon's rays at that moment, the fact should be stated. Every observation must also specify the maker's name and number of the time-piece employed, and whether the occultation was well observed, and if not, what amount of uncertainty attaches to it.

Great care must be taken to guard against errors of 10^s in the record, and, to this end, it will be well to have an assistant call aloud every tenth second, "0," "10," "20," etc.

The chronograph may be used in observing occultations, but in that case a fraction of a second will be required for the observer to become conscious of the phenomenon, and to give the signal, and this interval must always be estimated by the observer, and recorded in the memorandum-book. But, the chronograph should never be trusted to exclusively, and, when used, either the observer himself or his assistant should note the chronometer time of the occultation, or of the signal with the key.

XXXVI.—GENERAL INSTRUCTIONS RESPECTING OBSERVATIONS OF CONTACTS.

The first question which the intending observer of contacts has to consider is whether the appliances at his disposal and the circumstances in which he is placed will permit of his making observations of astronomical value. If they do, especial pains and minute attention must be devoted to all the necessary preparations. The following is an outline of the general plan of operations:

Determination of time.—The most essential requirement is that the observer shall have the means of determining his local time within at least one or two seconds At fixed observatories there need be no difficulty in this respect. For the benefit of observers at other points it is intended to make arrangements with the Western Union Telegraph Company to transmit time-signals from the Naval Observatory to every part of the country. Individual observers who receive their time in this way should communicate with the authorities at the nearest telegraph station, and, in the event of any doubt, address the Superintendent of the Naval Observatory, Washington, on the subject. Detailed information and instructions for receiving and understanding the time-signals will be sent to all who desire it in advance of the transit.

Size and quality of telescope.—The aperture of telescope to be preferred in the observations is from 5 to 6 inches. In order that all observations may be as nearly as possible comparable with those made in the Southern hemisphere, it is recommended that observers with telescopes exceeding 6 inches in aperture reduce the aperture to 6 inches in observing all the contacts. Apertures as small as 4 inches may be used without seriously detracting from the accuracy of the observation. Below 4 inches the value rapidly diminishes, and 3 inches may be regarded as the smallest with which observations of real value can be made. It is important that the objective should be of good quality, forming round, neat images of stars, with a power as high as 200. To test the objective, alternately push the eye-piece in and draw it out so that the star shall present the appearance of a disk of light. If the objective is good, this disk will be round and of uniform brilliancy; if the disk is irregular in outline, with permanent bright or dark regions in it, it shows the telescope not to be good.

Magnifying power.—The eye-piece should have a magnifying power not less than 150 nor much more than 200. Between these limits the choice may be regarded as indifferent.

Mounting.—An equatorial mounting is nearly indispensable to an accurate observation. Observers practiced in the use of an altazimuth mounting may possibly make an observation with one of that class, but they must be able to keep an object in the center of the field. A clock-motion is desirable, though not indispensable. If there is no clock-motion the telescope must be firmly mounted, and the observer must be well practiced in moving the eye-piece steadily with his hand so as to keep an object in the center of the field.

Micrometer.—A regular filar micrometer will not be of any use as an instrument of measurement, but spider-lines of some sort are desirable for the double purpose of insuring an accurate adjustment of focus and of estimating the brilliancy of the sun's disk. If the telescope is not supplied with a micrometer the observer should have a positive eye-piece, in the focus of which he should insert a spider-line or, better yet, if he is able to do it, a pair of spider-lines at such a distance that the angle between them shall be $1''$ or $2''$ of arc. In a 6-foot telescope the required distance will be about $\frac{1}{2000}$ of an inch. The observer should find by previous trials on the sun and stars the exact point when the spider-lines are in the focus of the objective so as to insure their being in proper position on the day of the transit. This point may be indicated by a mark on the eye-piece.

Shade glasses.—The common sun-shades, consisting of a single piece of thick glass, are very apt to split, and thus endanger the observer's eye, if the rays of a bright sun are concentrated upon them by an objective of larger aperture than two inches for a focal distance of thirty inches, or three inches for a focus of five or six feet. By making the shade of three thicknesses of glass, the piece next the eye being thickest and darkest in color, the other pieces being successively thinner and lighter in color, and all being fitted loosely into their cell so that they can expand freely, it will be possible to use with safety an aperture of five inches upon a telescope of six feet focus. It is, however, recommended that, wherever possible, some other means of diminishing the sun's light be employed. Silvering the objective might be recommended, except for the possibility of cutting off too much light in a hazy atmosphere. The polariscopic eye-piece is commended for its convenience in use. If the observer cannot avail himself of it, a diagonal eye-piece with a reflector of plain unsilvered glass is recommended. In such an eye-piece the reflector is placed a little in front of the focus at an angle of 45° with the axis of the telescope. Being unsilvered, 92 per cent. of the light passes through it, and should be permitted to leave the telescope through an opening so as not to heat the air or the reflector. The remaining 8 per cent. of the light is reflected from the two surfaces of the glass. In order that these two systems of reflected rays may not cause confusion, the glass should be ground wedge-shape, and so arranged that only the reflection from the first surface may reach the eye. Since 4 per cent. of the sun's light will in nearly all cases be too great for the eye, the observer should also be provided with shade-glasses to still further diminish it. A neutral tint is to be preferred for all such glasses.

Day of the Transit.—It is essential that every observer intending to make a really accurate observation should have little else to attend to during at least an hour or two before the first contact he is to observe, and should be entirely free from visitors and inquirers. The points to be particularly attended to are the firmness of the telescope, his ability to move it in such a way as to keep any required part of the sun's limb steadily in the center of the field, and the accuracy of the focal adjustment. A mere estimate of an accurate focus about the time of observation should not be trusted to if it can be avoided, because the eye itself is liable to change its accommodation in this respect. The surest course is to have a pair of spider-lines previously fixed in the astronomical focus and to adjust the eye-piece so that these lines shall be sharply defined on the sun's disk. The observer can then be certain that his focus is right so long as the definition of the wires continues good.

The degree of brilliancy of the sun's disk as seen by the eye is to be particularly attended to. It was recommended by the Paris International Conference that the disk should be darkened to the point at which a pair of spider lines 1″ apart could just be seen distinctly separated. But as this test may not suffice, and as the observer may find insuperable difficulty in fixing the wires so close to each other, some other tests should be employed. We may lay down limits as follows:

I. If the brilliancy of the disk is such as to be at all unpleasant to the eye, or if there is any appearance of glare* surrounding the sun's limb, then the light is too bright and must be diminished.

II. If there is any difficulty in seeing the limb well and brightly defined, then the light is too faint. Perhaps a good rule will be to shade off the light to such a degree that with the center of the sun in the center of the field, the whole field is as bright as the observer finds it not unpleasant to look at continuously, and yet not so bright as to render the mottling of the photosphere indistinct. Then, since the sun's limb is

* This word is here used, not in the sense of a general atmospheric illumination, but in the sense of such a refulgence as to produce an appearance of indistinctness of outline through that excitation of the eye itself known as *dazzling*.

less than half as bright as the center of its disk, it may be presumed that the latter will be about of the right shade. But it must always be remembered that the slightest glare indicates too great a brilliancy.

Yet another guiding rule will be that the most distinct and easy view of the sun's limb is to be aimed at.

External contact.—To make a really good observation of this contact two conditions are essentially necessary in addition to all which have been described. The observer must have had some previous practice in observing first contacts, and he must know exactly where to look for the contact.

The first condition can be well fulfilled by the artificial transit of Venus apparatus, of which it is intended to have one or more in Washington available for observers.

For the second condition it is essential that the observer shall have the means of setting the spider-lines in the field of view to any required angle of position. Within the United States the first contact will occur at a point of the limb found by measuring 147° from the north point towards the east. The spider-lines should be set at right angles to that radius of the solar disk which terminates at this point of the limb. Then cutting off a segment of the disk by the spider-line, first contact will be seen in the middle of this segment. The tabular time of first contact at any point on the earth's surface may be found within a minute by subtracting 21 minutes from the time of internal contact. The interval between these contacts may be found with yet greater precision from the tables in the American Ephemeris for 1882. The tabular Greenwich time of internal contact may be taken at sight from the proper map accompanying this paper. Within the United States the tabular time of first contact may be regarded as 20 hours 55 minutes Washington time. In civil reckoning this is five minutes before nine a. m. Owing, however, to the errors of the tables, which observations of the transit will help us in correcting, it is quite possible that first contact will occur a large fraction of a minute earlier than the predicted time. To allow for this possible error, it is recommended that the observer begin to look exactly one minute before the computed time. The following is a specimen of part of the computation which the observer should make by the aid of the chart in order to know when to begin looking. Suppose the place to be Cincinnati. We find from the chart:

	h.	m.	s.
Greenwich mean time of internal contact	2	24	52
Longitude of Washington	5	8	12
Washington mean time	21	16	40
Reduction to external contact		21	15
Washington time of tabular contact	20	55	25
Washington time to begin looking	20	54	25

The observer should avoid looking before this time in order not to fatigue his eye.

The time to be noted is that at which the notch made by the advancing planet first becomes visible. The observer may have to wait a few seconds to be sure that what he sees is really a permanent notch, but the time to be given is that when it was first certainly seen. If he did not catch the first moment when he could see it, that fact must be stated.

Internal contact.—Owing to the importance of this observation and the necessity of special attention to it, it is recommended that the observer have little else to attend to during the 21 minutes between it and external contact. It is now believed that measures of the cusps with a double-image micrometer should not be undertaken during this interval, owing to their fatiguing the eye and distracting the attention of the observer.

It is essential that the observer should allow his eye nearly perfect repose for several minutes before the contact. It is quite right and proper that he should take a general view of the phenomenon at short intervals, and note the appearance presented by the outline of the planet, but he should not exercise his eye and attention in endeavoring to make any difficult observation.

His serious attention will be first required some two minutes before the expected time of contact. There is every reason to believe that the entire outline of the planet will then be visible, that portion not on the solar disk being bounded by a fine line of light, supposed to be due to the refraction of the atmosphere of the planet. Indeed, this line may be visible from the first moment of the planet's appearance, and the changes which it undergoes in the relative brilliancy at different points will be a subject of great scientific interest. Although observers of accurate contacts must guard against fatiguing their eyes by minute observations on this arc of light, observers who have not the appliances for making the best observations of contact might well devote themselves to its careful study.

One of the great difficulties in the observation of internal contact will be to avoid confusing this line of light, which may grow brighter as contact approaches, with the direct light from the sun's limb, which will be seen after contact. The distinction of the two is a matter of judgment which must be left with the observer. In what follows we, for the most part, make abstraction of this appearance, describing phenomena as if it were not present, and the observer must in like manner seek to observe as if it were not present.

The moment to be observed as that of true internal contact is when the limb of Venus is exactly tangent to that of the sun. It is, however, found by experience that, although easy to think of this tangency, it is difficult to observe it with the requisite precision, owing to the imperfection of vision, and especially to the irradiation produced by the earth's atmosphere and by any imperfections in the telescope. The phenomena to be really observed are defined as follows in the instructions of the International Conference held at Paris in 1881:

> "At ingress the moment to be noted is that at which the observer sees for the last time an evident and persistent discontinuity in the apparent limb of the sun near the point of contact with Venus."
>
> "At egress the moment of the first appearance of a well-marked and persistent discontinuity in the illumination of the apparent limb of the sun at the point of contact."

However well these definitions may apply to the actual phenomena, they are not sufficient, without further explanation, to enable the observer to know what is contact under all circumstances. Indeed, the Conference itself added a number of instructions of what was to be looked for under special circumstances. For these instructions the following are, however, substituted by the American Commission.

We must first remember that just before internal contact at ingress the sun's limb will be broken off by the advancing planet, and that portion which is visible near the point of contact will present the appearance of two fine sharp horns, the points of which will slowly approach each other. The moment of true internal contact is evidently that at which these points exactly meet. But since they cannot be seen by the eye to meet until the completed line of light becomes thick enough to be seen, the observer must not expect to see the thread of light actually complete until after the contact has passed. As a general rule, therefore, he must note what is to be seen just before this thread of light becomes evidently complete. What he sees will depend very largely upon the clearness and steadiness of the air. The most favorable circumstances for observing true contact are those in which the cusps appear steady and sharply defined against the black background of the sky. There will then be little difficulty in catching the moment at which they are first about to meet, which will be that of true contact.

In most cases, however, especially if the sun is low, the outline of the cusps will be wavy and serrated, their ends will be more or less rounded instead of being sharp, and their outline will be continually changing in consequence of the apparent undulating motion produced by the atmosphere. The greater this vibratory motion and the more the cusps are blunted the more difficult it will be to catch the moment of true contact. The following rules are then to be borne in mind by the observer: So long as the dark region between the cusps which connects the black disk of Venus with the black sky outside the sun retains its full darkness, without any apparent motion or undulation going across it, so long contact has not occurred; and this although the planet may seem entirely within the true outline of the sun. It would be well for the observer to have an assistant at the chronometer to whom he can from time to time call out the words "not yet." The assistant should write down the second by the watch or chronometer at which the observer commenced to pronounce these words.

Instead of the cusps uniting into a fine, steady line of light, the observer may at a certain moment begin to see an undulating motion extending all the way across this dark space. He will soon after see that this motion is due to the continually increasing line of light, which is broken into threads and waves by atmospheric undulation. From and after the time that this undulation is permanently seen contact is certainly passed. It would be well, when it is first fully recognized, that the observer should call out "past" to his assistant, who should note the time at which the word is spoken. If he has made no mistake in his estimates the time of contact will be limited between the last moment at which "not yet" was spoken and the first moment at which "past" was pronounced.

In the event of the cusps appearing much rounded, the further Venus appears inside the disk of the sun, as completed in the imagination by continuing its outline across the dark region, the more careful must the observer be to catch the first line of true sunlight extending across. It may be assumed that if the seeing is at all good the undulating light of the sun's limb will be clearly recognized in a very few seconds after the true time of contact. On the other hand, he must be on his guard against mistaking some slight haziness around the point of contact for the appearance of true sunlight. It is also possible, in case of a very bright but undulating image, that the sharp cusps may from time to time be momentarily brought together by atmospheric undulations before contact really occurs. These are points upon which the observer must be left to his own judgment. He must in all cases try to estimate what the phenomenon would be if there were no undulations, and he will be assisted in this by taking particular note of the appearance at those moments of steadiness which generally occur every few seconds in the worst atmosphere. The trouble to which observers are prone is that of catching some phenomenon or undulation, which really occurs only from time to time, and fixing the attention on it as though it were permanent. It is so easy to imagine that one sees irregular phenomena that the observer must be especially careful to distinguish what is permanent from what is an accidental product of atmospheric vibration.

The preceding directions apply principally to those cases in which the air is clear and the sky blue. If the observation is made through a sky so covered by clouds or haze that there is no striking contrast between the brilliancy of the sun and that of the surrounding sky, the observation may be extremely difficult, because the completion of the thread of light will probably not be seen until a considerable period after actual contact. It is therefore best in such cases that the observer should note the last moment at which he felt sure the limbs did not become tangent and the first moment at which it became permanently evident that the planet had passed entirely within the sun. Perhaps no better definition can be given of contact under such circumstances than that it is the moment when the limbs are really tangent.

Whatever moment the observer may note, it is indispensable that he give an accurate statement of the appearance presented by the sun and planet at that moment, accompanied by a drawing if necessary. If he is able also to give a drawing or description for the moment at which he last spoke the words "not yet," and at which he first said "past," it will be well to do so. At the same time the useless multiplication of times is to be guarded against, owing to the distraction thus produced.

Egress.—At egress the phases occur in inverse order, so that the same directions will apply when properly interpreted with the respect to time. The following points are, however, to be especially noted:

As the thread of light between the limbs of the sun and planet becomes very thin it will probably appear to darken, partly from atmospheric irradiation and partly from the eye being less affected by a thin line than by a broad band of equal brilliancy. If the atmosphere is undulating this thread may be expected to break up into a mass of undulating threads of light, continually changing their form and appearance. So long as this undulating mass continues to be seen in motion all the way across the dark space near the point of contact, so long contact has not occurred. If, however, the appearance of congealing into a hard immovable mass is presented, the moment of such seeming congelation is that of true contact.

In looking for the complete disappearance of the undulating light the observer must be on his guard against mistaking the illumination of the outline of Venus, produced by the atmosphere of the planet, for the true light of the sun's limb. There were supposed to be some cases during the transit of 1874 in which the observer, watching for the fading line of light to disappear, found himself really observing this atmospheric outline after contact was past. This is a point on which, in the absence of complete experience, no definite instruction can be given to the observer, and he must rely upon his own judgment to guard against a mistake of this kind.

In the case of parties supplied with double-image micrometers it is recommended that measures of the thickness of the band of light between the two limbs be commenced as soon after internal contact as the observer has made all his necessary records and notes. It will also be well, twenty minutes before second internal contact, to commence similar measurements of the thickness of the point of light between the limbs. Great care must, however, be taken to stop these measures and replace the micrometer by the eye-piece in good time to make a careful observation of contact.

Last contact.—The observer should note the last moment at which he certainly and distinctly saw the vanishing-notch made by the receding planet. To assist in this it will be well to pronounce the word "notch" from time to time and have the times noted by the assistant.

XXXVII.—METHODS OF RECORDING CONTACTS.

To make the best possible observations of contacts the observer must be well prepared to note the times of such phenomena as he may see, and this without any liability to errors of 10, 20, or 30 seconds, or a whole minute. If he has to look at and read a time-piece himself there is danger of such errors. They may be avoided by employing a chronograph, but in observing contacts there are two difficulties connected with the use of this instrument. The first is that in the event of other signals than those of contact being made, whether by accident or design, it may be difficult to recognize the meaning of the several signals. The second is that in general the instant of contact can be recognized only by watching the course of the phenomena both before and after that event, and thus the observer is not ready to record the contact till some seconds after it has occurred. Still, with proper precautions against these difficulties, a chronograph may be used.

Experience has shown that when an observer notes the times himself, the surest way of guarding against errors in the seconds is to have an assistant at the clock or chronometer to beat every second with a key, or small hammer, upon a board. By this plan a pocket watch may be used in the absence of a better time-piece. At the moment of each beat the assistant must call out only the units or the tens of the second. Thus, beginning at ten seconds, the calls will be ten, one, two, three, etc., twenty, one, two, etc., thirty, one, two, etc. The reason for not calling the numbers in full, twenty-one, twenty-two, etc., is that their distinct pronunciation would require such a considerable portion of a second that the observer might be in doubt which beat any one number belonged to. The simple numerals from one to ten may be pronounced simultaneously with the beats, so as to leave no doubt. An assistant beating in this way may give time to several persons.

If the observer employs an assistant at the time-piece to read off and record his times, he must also arrange beforehand a system for registering notes respecting the phenomena. Such notes will be "not yet," "haziness near the point of contact," "flashes around the planet before contact," "atmosphere of Venus clearly illuminated," etc. If several such notes have to be made, two assistants will be necessary—one to write them down and the other to record the times. To co-ordinate the notes with the times, the letters A, B, C, etc., may be employed. The assistant at the chronometer is then to record the chronometer time at which the letter was spoken, and opposite it the letter itself, while the other assistant is to write down first the letter and then the note.

XXXVIII.—DIAMETER OF VENUS.

If the chief of party can spare any time from the photographic operations between second and third contact, it should be employed in measuring the diameter of Venus with the double-image micrometer. Such measures may be made in groups of sixteen, viz: Four measures of the polar diameter, two of them being made with the index to the right of zero, and two with it to the left; eight measures of the equatorial diameter, four being with index to right, and four with index to left; and lastly, four more measures of the polar diameter, two being with index to right, and two with index to left. By this arrangement the zero point and all errors symmetrical with the time are eliminated. FORM II contains some observations of the diameter of Mercury, made during its transit in May, 1878, at Austin, Texas, which are given as a specimen of such work. The numbers in the first column are, the chronometer time when the measurements were begun, namely $9.14 = 9^h\ 14^m$; the reading of an aneroid barometer, 28.98 inches; the temperature of the air, 92° Fahrenheit; and the chronometer time when the measures were finished, $9.30 = 9^h\ 30^m$: The other columns are sufficiently explained by their headings. One revolution of the micrometer-screw is equivalent to 17″.208, and the diameters are the product of the sums by one-quarter of this value.

FORM II.

Time, Barom. Ther.	Diameter Measured.	Readings of Screw.		Differences.	
		To Left.	To Right.	Polar.	Equatorial.
		r.	r	r.	r.
9.14	Polar . . .	14.91	13.51	1.40	. . . . . .
. . . .	. . . . . .	.91	.51	1.40	. . . . . .
. . . .	Equatorial .	14.91	13.51	. . . .	1.40
28.98	. . . . . .	.92	.54	. . . .	.38
92.0	. . . . . .	.93	.53	. . . .	.40
. . . .	. . . . . .	.92	.52	. . . .	1.40
9.30	Polar . . .	14.91	13.51	1.40	. . . . . .
. . . .	. . . . . .	.91	.52	1.39	. . . . . .
Sums				5.59	5.58
Diameter of Planet				24″.05	24″.00

XXXIX.—DATA REQUIRED.

For convenience of reference, the data which will be required in reducing the observations are here enumerated. D 3, 4, 5, 6, 7, G 3, 6, 8, 9, 10, H 3, and K 4 can be best determined in Washington. All the others must be determined in the field, and it will be the special duty of the chief of party to see that nothing needful is omitted from the record.

A.—Name of station.

B—Latitude and longitude of station.

C.—With every observation, the name of each person employed in making it, and the part he took in the work, must be recorded.

D—For the meridian instrument:

1. Maker's name and number.
2. Size and power of telescope.
3. Correction for flexure.
4. Correction for inequality of pivots.
5. Value of scale of striding level.
6. Value of scale of zenith distance level.
7. Value of one revolution of the micrometer screw.
8. Intervals of transit wires.
9. Intervals of micrometer wires.

E.—For the chronometers:

1. Makers' names, numbers, and descriptions, whether mean time or sidereal, number of hours on dial, break-circuit or not, etc.
2. The correction of each chronometer to local time whenever it is used.

F.—The maker's name, and number of the chronograph.

G.—For the photoheliograph:

1. Number of objective.
2. Number of measuring-rod.
3. Length of measuring-rod at some definite temperature.
4. Temperature of measuring-rod whenever it is used.
5. Number of jaw-micrometer.
6. Correction to be applied to readings of jaw-micrometer.
7. Distance from back surface of objective to front surface of reticule-plate.
8. Distance from back surface of the objective to its second principal point.
9. Thickness of reticule-plate.
10. Refractive index of reticule-plate.
11. Interval between reticule-plate and collodion-film.
12. Azimuth of the center of the reticule-plate.
13. Level, or zenith distance, of the center of the reticule-plate.
14. When the instrument is in use, the temperature of the atmosphere in the shade, the temperature in the photographic house, and the reading of the barometer and its attached thermometer, must be recorded every half hour.

G.—For the photoheliograph—Continued.

15. Every negative must have its number marked upon it by a diamond. With each negative must be recorded the chronometer time of its exposure, a sidereal chronometer being used; the direction (east or west) of the small arm on top of the frame, from the center of which the plumb-line is suspended; and the direction of motion of the exposing-slide (east or west).

H.—For the engineer's level, or level of precision:

1. Maker's name and number.
2. Size and power of telescope.
3. Value of level-scale.
4. Value of micrometer-screw.

I.—For the theodolite:

1. Maker's name and number.
2. Size and power of telescope.
3. Diameters of limbs, and least reading.

K.—For the equatorial telescope:

1. Maker's name and number
2. Size of telescope.
3. Powers of eye-pieces.
4. Value of one revolution of the screw of the double-image micrometer for each of the two front lenses.
5. With every observation, the power employed in making it must be recorded.

The utmost care must be taken to have accurate knowledge of the local time on the day of the transit. Owing to the uncertainty of weather, no fair night must be allowed to pass during the week preceding December 6 without the observation of star-transits for time and azimuth; but if clouds prevent such observations, then, if possible, the transit of both limbs of the sun must be observed daily during the same period, the telescope being reversed between the limbs. On the day of the transit all the chronometers at the station must be compared in the morning, and again in the evening.

On December 5th all the apparatus must be inspected to make sure that it is in good working order, and care must be taken that the adjustments 4 and 5 of section V are correct. Both on the day of the transit and on the day preceding, G 7 and G 13 must be very accurately determined; and G 12 must be deduced from the transits of stars observed on nights before and after the transit of Venus, but as near to that event as possible.

Examples showing how observations of G 13 should be made and recorded are appended. In explanation of them it is only necessary to say that FORM III refers to observations with an engineer's level, and FORM IV to observations with a level of precision. The theory of these observations has been already given in section V. That end of the bubble which gives the largest reading is toward the high end of the line, and the amount of elevation is found by multiplying the number in the line "Difference" into one-sixteenth of the value of one division of the level scale. For the level Stackpole and Brother, No. 1510, the valve of one division was 6″.54. One-sixteenth of this is 0″.409, which multiplied by 9.8 divisions gives 4″.01. For the level

Stackpole and Brother, No. 1489, the value of one division is 1″.74, one-sixteenth of this is 0″.109, which multiplied by 22.0 divisions gives 2″.40. The large collimation error of the telescope of this level is noticeable.

FORM III.—*Observations made with the engineer's level* STACKPOLE *and* BROTHER, *No.* 1510, *to determine the inclination of the line of collimation of the horizontal photoheliograph at Hobart Town, Tasmania, December* 9, 1874.

Object Observed.	End of Bubble.			
	North.	South.	North.	South.
	d.	d.	d.	d.
Reticule .	45.0	13.9	. .	. .
	44.6	13.9	. .	. .
Transit .	. .	. .	12.0	43.0
	. .	. .	12.5	43.4
	. .	. .	12.2	43.3
	. .	. .	12.2	43.0
Reticule .	44.0	13.0	. .	. .
	44.0	13.0	. .	. .
Sums . .	177.6	53.8	48.9	172.7
Sums . .	231.4		221.6	
Difference	9.8			
North end high, 4″.01				

FORM IV.—*Observations made with the level of precision,* STACKPOLE *and* BROTHER, *No.* 1489, *to determine the inclination of the line of collimation of the horizontal photoheliograph at Washington, D. C., September* 9, 1882.

Focusing Pinion.	End of Bubble.	Level Direct.	Level Reversed.
Right .	N.	23.5	44.0
	S.	51.5	15.0
Left . .	N.	13.0	54.0
	S.	42.0	25.5
	N.	12.0	55.0
	S.	41.0	26.0
Right .	N.	23.0	44.5
	S.	51.5	15.5
Sums		257.5	279.5
Difference . . .		22.0	
North end high, 2″.40			

XL.—RECORDS OF OBSERVATIONS AND OPERATIONS.

Of the journals and memorandum-books, each observing-room is to have at least one for its exclusive use, in which every operation must be recorded in detail, with all the particulars necessary to its being fully understood. A journal is also to be kept, in which all the operations of the party must be entered.

In addition to the original record of the observations, a duplicate record must be made with ink, at the earliest possible moment. The following rules respecting the correction of supposed mistakes must be attended to in the case of each set of records:

Original rough record.—In this record a number once written should never be erased. If the observer detects a wrong number immediately after writing it, he must draw a line through it and write the correct number beside it. If it is concluded from subsequent observations that a number is probably wrong, that fact must be noted, and the correct number indicated; but the record as written must not be altered. Numbers should not be inserted in this record which are the result of calculation. For instance, if the observer fails to note the minutes of the chronometer corresponding to any observation, he must not conclude what they were from the preceding or subsequent observations, and then put them in, but must omit them entirely, unless such omission would cause subsequent uncertainty. In that case the necessary numbers may be inserted, provided it is done in such a manner as to show that they were not directly observed, but are concluded from other parts of the record. To indicate this, a circle may be drawn around them.

Should it be found necessary from any cause whatever to make the first rough notes of an observation upon loose slips of paper, these slips must be carefully pasted into the proper note book, in immediate proximity to the formal record which has been copied from them.

The duplicate or fair copy.—The second record is to be copied from the first as soon as practicable after making the observations, so that if mistakes exist they may be detected and corrected. If blank forms for the observations are provided, they may be used for the second copy as well as for the first; but everything for which they are not available must be copied in chronological order into a single book. In this duplicate copy greater liberty will be allowed respecting additions and alterations than in the original, the object being to make a complete and correct record; but in the event of numbers being added as the result of calculation, they should be underscored with red ink, or otherwise indicated.

All records of observations must include every particular necessary to their being completely understood. For instance, wherever time is given, the particular timepiece employed must be designated; where level readings are given, the direction of each end of the level, east, west, north, or south, must be recorded; when the images of lines on the plate-holder are observed with the transit, the direction of the image from the middle wire, whether right, left, north, or south, must be stated, as well as the direction of the eye-piece of the instrument, east or west; and all photographs of the sun must indicate the exact time at which they were taken, and must be so marked that the position of the plate when in the holder—that is, the top, bottom, east and west sides—can always be distinguished.

In using the chronograph, the minutes and seconds must always be marked upon the sheet at least twice during each series of observations. All chronograph sheets must be preserved and sent home with the other original records, but in addition to this they must also be read off and recorded in the proper books.

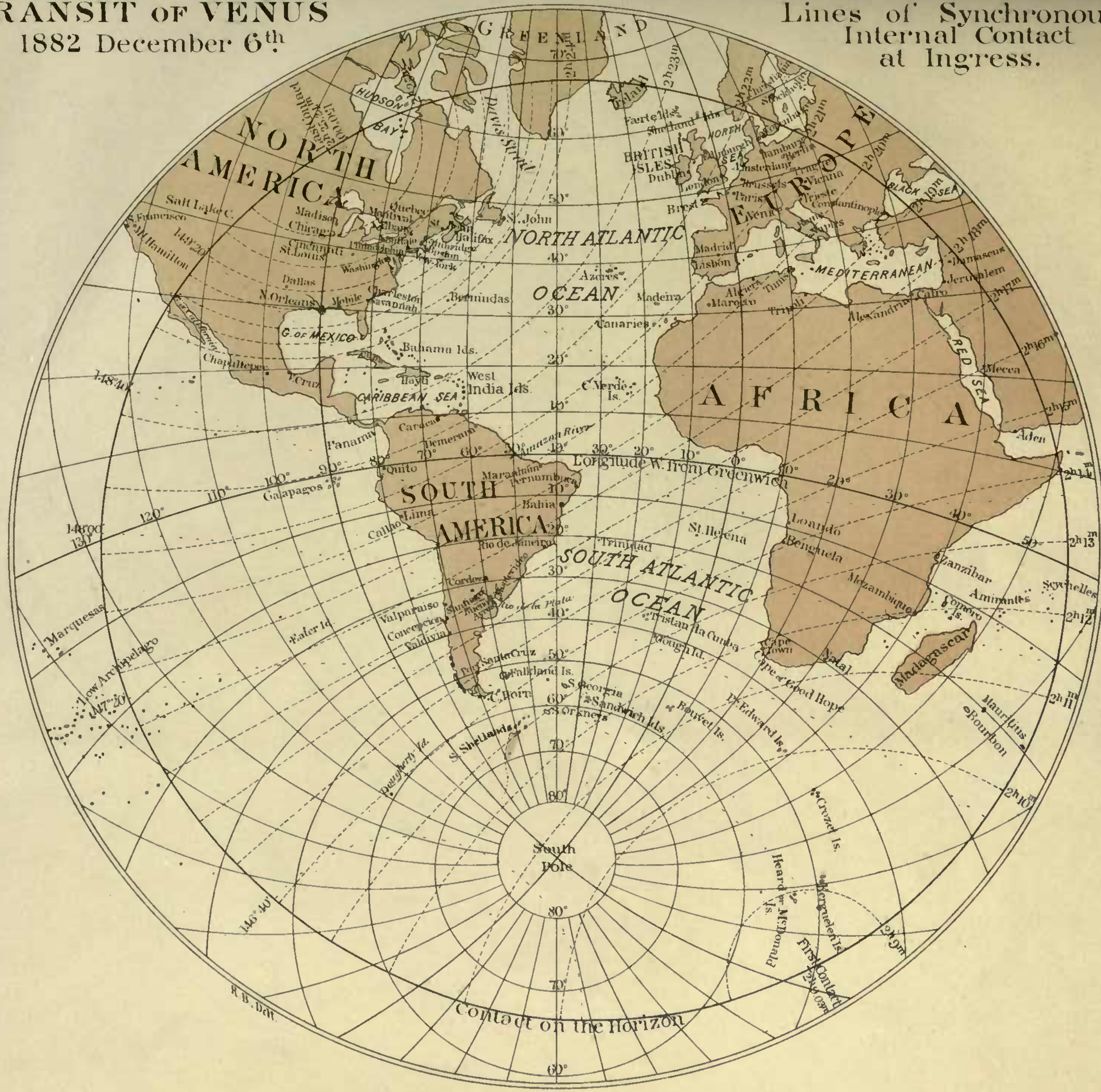
XLI.—TRANSMISSION AND PUBLICATION OF OBSERVATIONS.

All members of the parties are prohibited from publishing their observations, or results, without authority of the commission; but this prohibition is not intended to prevent any general statements respecting the nature and success of the work which the observers may choose to make. In cases of co-operation with any other individual or party, the chief of the party is authorized to communicate to the other copies of all observations necessary to the special end for which the co-operation was entered into.

The chief of each party will transmit all the records to the president of the commission as soon as practicable after the completion of the observations. They will be sent in separate packets, one containing the journal and all the original pencil memoranda of the observations, the other the fair copy already directed to be made. If practicable, the two packets must be sent at different times and by different conveyances. From ports where an American consul is stationed, they may be forwarded by him through the Department of State, in which case he must be notified to send the two packets by different ships.

TRANSIT OF VENUS
1882 December 6th.

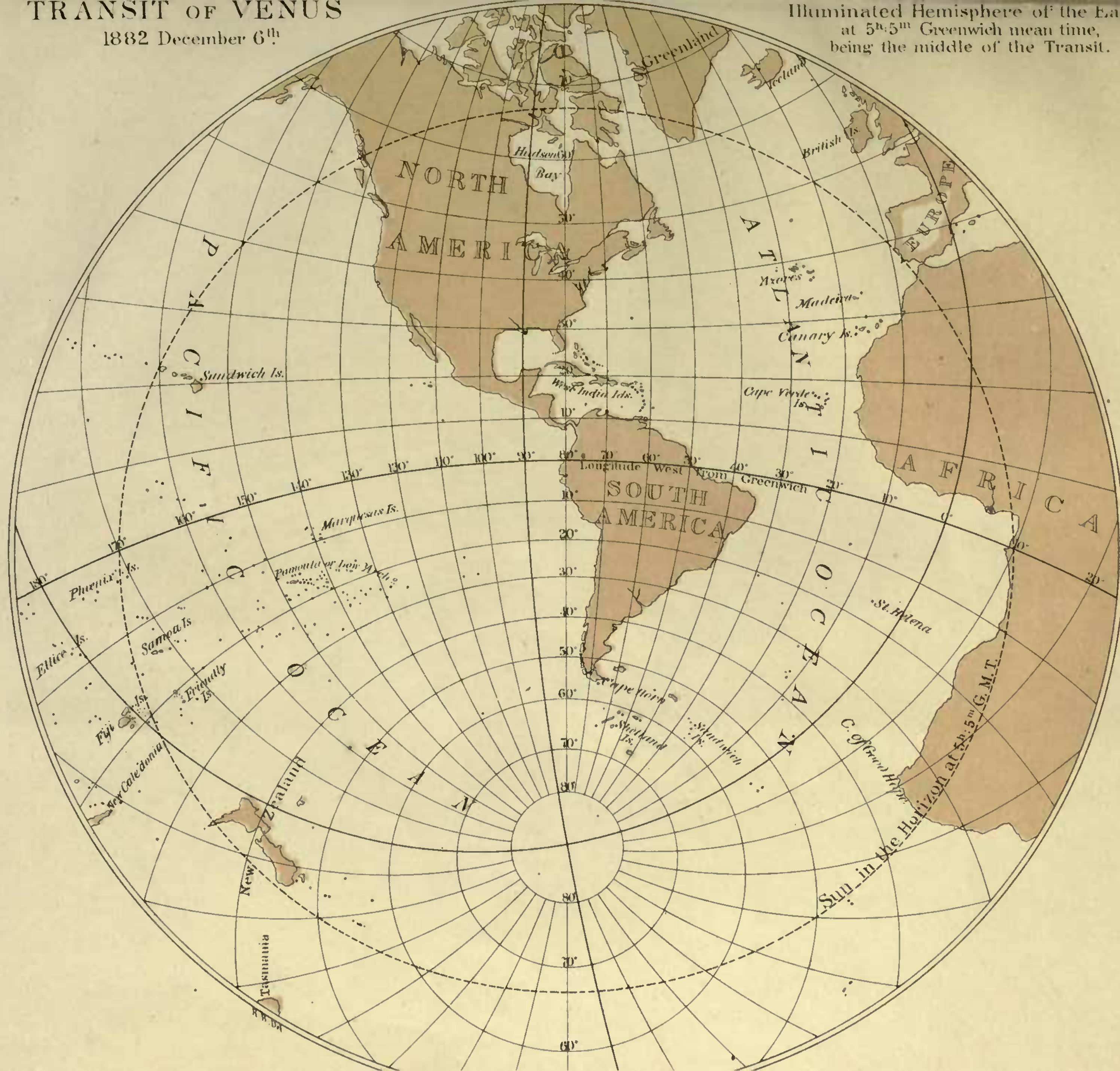
Lines of Synchronous Internal Contact at Ingress.



TRANSIT OF VENUS

1882 December 6th.

Illuminated Hemisphere of the Earth at 5h.5m Greenwich mean time, being the middle of the Transit.



TRANSIT OF VENUS
1882 December 6th.

Lines of Synchronous Internal Contact at Egress.

TRANSIT OF VENUS
1882 December 6th.

Paths described by several Stations
through diurnal motion
as seen from the Sun
during the Transit.